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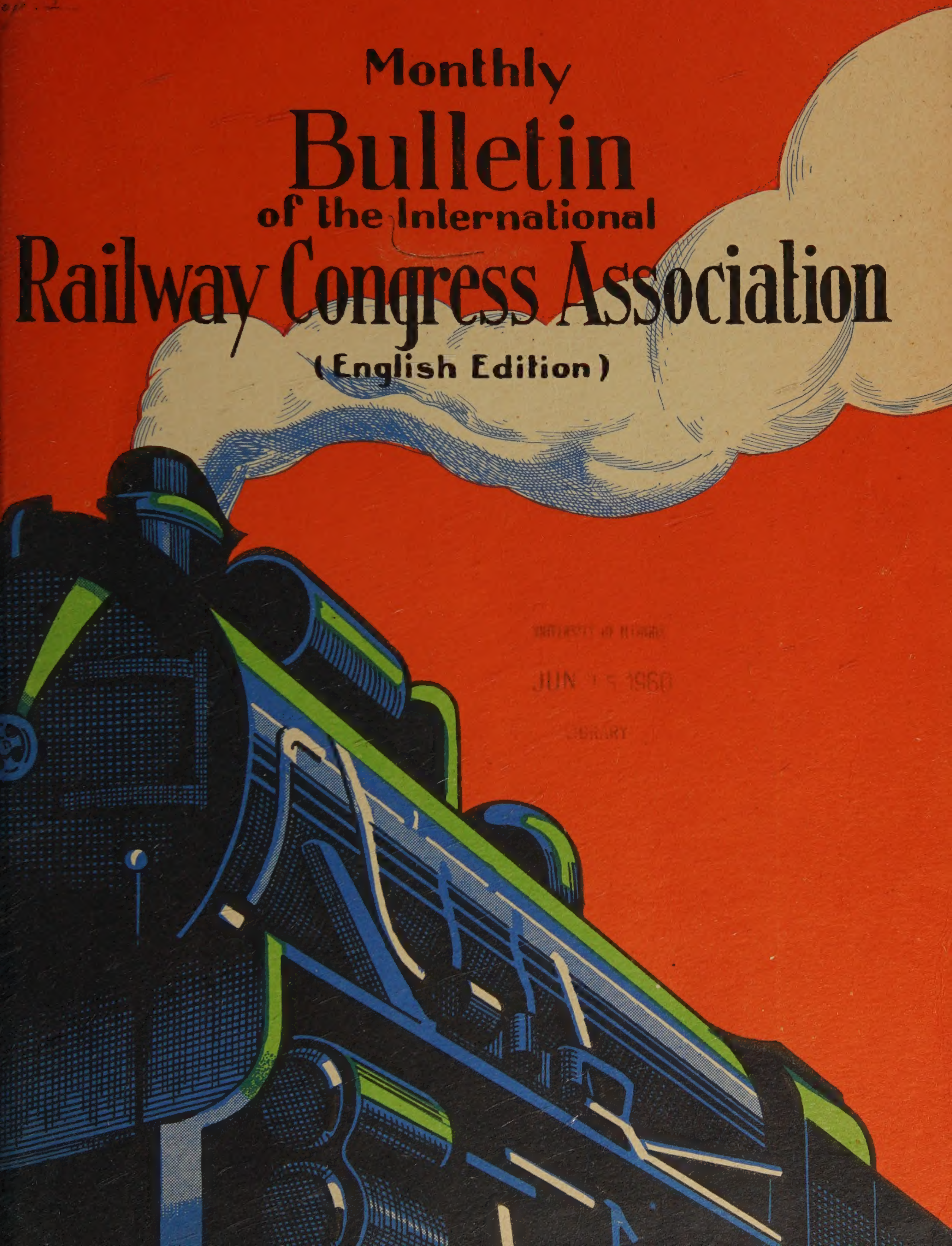

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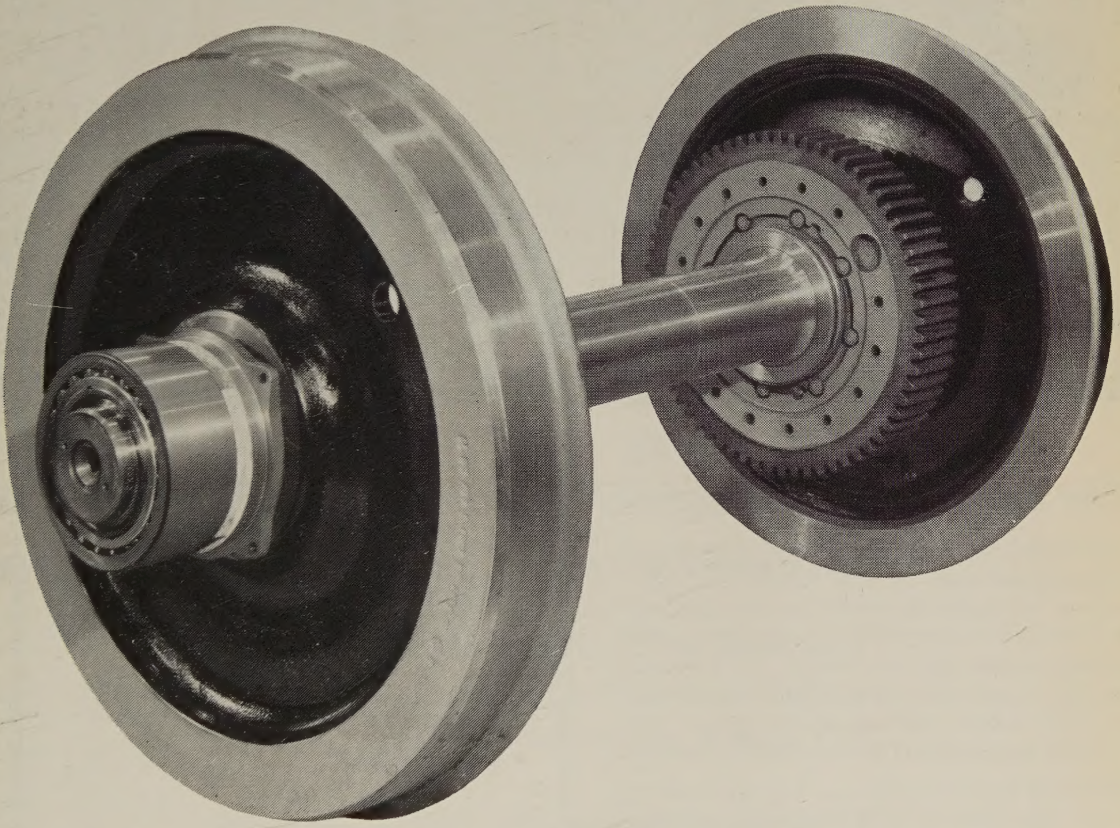

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COCKERILL-OUGREE

SERAING (Belgium)

MONTHLY BULLETIN

OF THE

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

(ENGLISH EDITION)

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Vol. XXXVII. — No. 5. May 1960.

BULLETIN
OF THE
INTERNATIONAL RAILWAY CONGRESS
ASSOCIATION
(ENGLISH EDITION)

[656 .25]

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

ENLARGED MEETING OF THE PERMANENT COMMISSION
(BRUSSELS, 1960).

QUESTION 1.

The effect of electric traction on signalling and communication circuits, in particular reference to the means of overcoming interference, to provide safety and good communications.

REPORT

(Austria, Belgium and Belgian Congo, Bulgaria, Cambodia, Czechoslovakia, Denmark, Ethiopia, Finland, France and French Union, West Germany, Greece, Hungary, Indonesia, Italy, Lebanon, Luxemburg, Poland, Portugal and overseas territories, Rumania, Siam, Spain, Switzerland, Syria, Turkey, Viet-Nam and Yugoslavia),

by Prof. Dr. Eng. R. Righi,

Directeur de l'Institut Expérimental des Chemins de fer de l'Etat Italien, Rome.

CHAPTER I.

TRACTION SIDE.

The questions put in the first chapter are largely concerned with the characteristics and features of the electric traction system and its installations. In view of the descriptive character of the replies, many of which are in the form of figures, it has been deemed advisable to tabulate the more important data in the attached tables, distinguishing between D.C. systems (Part A) and A.C. systems (Part B).

Any supplementary data which did not lend themselves to tabulation have been included in the following notes.

It should be pointed out that these tables do not represent a comprehensive and litteral transcription of all the replies but merely a synopsis of the principal data, a convenient framework mainly designed to simplify and shorten the analysis and summing up which follows.

TABLE 1. — PA

	QUESTION	Con-secut. No.	Ques-tion No.	Units of measure-ment	S.N.C.B.	R.E.N.F.E.	S.N.C
1.1 — POWER SUPPLY — H.T. NETWORK	*Does the H.T. network belong to the railways?*	1			No	No apart from some lines	No
	Number of phases	2	1.121		3	3	3
	Frequency	3	-	c/s	50	50	50
	Rated voltage and permitted variations	4	1.122	kV	Mostly : 70 ± 5 %; otherwise : 11 ± 150	Several voltages ranging from 25 to 130±7 %	Most 60 ± som 45 an
	Traction load in per cent of total load	5	1.123	%	100 %	6 % (mean)	3 ÷
	Are the H.T. lines systematically parallel to the railway lines?	6	1.124		Not generally	Not generally	N
	Min. dist. of paral. H.T. lines fr. track	7	1.124	m			
	Mean dist. of paral. H.T. lines fr. track	8	1.124	m			
	Connections of neutral points	9	1.125		Insulated or solidly earthed	Insulated, or solidly earthed, or earthed over 10 ohms	Sol eart
	Selective distance protection	10	1.126		Yes	No	Y
	Maximum time for disconnecting a fault	11	1.126	Sec	0.4	1 ÷ 5	0
	Automatic reclosure	12	1.126		No	No	Y
	Phase transpositions	13	1.127		No	On long-distance lines only	Y

(1) On the extra H.T. network, single-phase (time lag 1.5 sec) and three-phase (slow, time lag several seconds); on the M.T. network, phase reclosure only.

. Electrifications.

F.S.	*P.K.P.*	*J.D.Z.*	*R.A.T.P.*	*ALGERIAN RAILWAYS*	*MOROCCAN RAILWAYS*	*D.B.*	*N.S.*
Yes		H.T. No M.T. Yes	Yes	No	No	H.T. No M.T. Yes	H.T. No M.T. Yes
3	3	3	3	3	3	3	3
50	50	50	50	50	50	50	50
Mostly : 0 ± 5 %; some :) and 150	15 and 30 + 5 % - 10 %	H.T. 110 M.T. 30; 50 ± 5%	10.25 ± 5% cabled	One line 90 ± 7 %	60 and 5.5 ± 10%	H.T. 100 ± 10% M.T. 25 ± 10% M.T. cabled	H.T.110 ÷ 150 M.T. 10 ÷ 25 ± 10% M.T. cabled
50%	30%	H.T. 17% M.T. 100%	100%	50%		H.T. 2.5% M.T. 80%	M.T. 100%
Yes	Yes	Yes	No	No, but the alignment is the same	No	M.T. Yes	Partly
100	15	3 000			500	4	
	30					4	
nsulated		Earthed through reactance	Insulated or earthed through reactance or resistance	Solidly earthed	Solidly earthed	Earthed through arc suppression coils	Insulated or earthed through reactance
Not yet		No	No	Yes (partly)	No	Yes	Yes
3	0.5	3		0.2 and 1			1.5
No	No	No	No	No	No	No	No
Yes	Yes	For 110 kV only		Yes	Yes	H.T. Yes M.T. No	

TABLE 2. — PA

		QUESTION	Con-secut. No.	Ques-tion No.	Units of measure-ment	S.N.C.B.	R.E.N.F.E. (4)	S.N.C
1.2 — SUBSTATIONS		*Number of rectifier phases*	14			6	6	6
		Protection grids	15	1.231		Yes	Yes	Yes
		Control grids	16	1.231		No	No	Yes
		Ripple reducers	17	1.232		No (sign. and telec. cabled)	Yes (resonant type)	No (sign. and cable
		Amplitude of the current harmonics in substation input	18	1.24		Not measured	Not measured	R.M.S. of the 17 harm 21-23.
		Short-circuit level at substation input	19	1.25	MVA	400 ÷ 1 500	700	100 ÷
	FEEDER PROTECTION	*Time for disconnecting a fault*	20	1.261	ms	30	5 ÷ 10 (5)	20 (
		Automatic reclosure . . .	21	1.262		Yes	No	No
		Earth tests	22	1.262		No(3)	Sometimes	
		Number of reclosures . . .	23	1.262				
		Intervals between reclosures	24	1.262	Sec			
1.3 — TRACTION SYSTEM		*Nominal voltage of traction system*	25		V	3 000	*a)* 3 000 *b)* 1 500	1 50
	LENGTH OF ELECTRIFIED LINES	*single-track*	26	1.31	km	7	*a)* 1 436 *b)* 464	9
		double-track	27	1.32	km	868	*a)* 300 *b)* 503	3 5
		total	28	1.33	km	1 743	*a)* 2 036 *b)* 1 470	7 9

(3) After an interval of 3 to 10 seconds, different for each feeder of the same substation.
(4) The RENFE replies on substations apply to 3 000 V electrifications only, and not to those of 1 500 V which are fed by 6-phase rotary conve
(5) It is possible that this figure does not include the arcing time.
(6) Ignition delayed at low load, natural commutation from nominal load onwards.

. **Electrifications.**

F.S.	P.K.P.	J.D.Z. (8)	R.A.T.P.	ALGERIAN RAILWAYS	MOROCCAN RAILWAYS	D.B.	N.S.
6	6	6	6	6	6	6	6
Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
No	No	No	Yes ?	No	No	No	No
Yes mostly eriodic)	Yes (9) (resonant type)	Yes (resonant type)	No	Yes (resonant type)	Yes (resonant type)	No	No
Not easured	Not measured	Not measured	Ripple coefficient < 3.5% at full load	Not measured	Not measured	Not measured	Not measured
) ÷ 2 000	200 ÷ 600	87 ÷ 220				M.T. 860	100 ÷ 350
) ÷ 100	20 ÷ 90	60	10 (5)	5 (5)	14 (5)	80	10 ÷ 20
Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Yes	Yes	Yes	Yes	Yes	Yes		Yes
3 ÷ 5	3	3	2	3	3		3
20	3 ÷ 30	15		30			10 ÷ 50
3 000	3 000	3 000	600	3 000	3 000	1 200	1 500
2 623		107	11	381	639	10	160
3 162		72	164	6.5	81	48	1 460
8 947		251	339	394	801	106	3 080

r a violent short-circuit.
e fixed substations will be replaced by single-set substations which can be transported on suitable trailers and work automatically.
e resonant type with a shunt capacitance of 50-100 μF has been adopted; the aperiodic type would be more expensive and would render the rking of the circuit breakers difficult.

	QUESTION		Con-secut. No.	Ques-tion No.	Units of measure-ment	S.N.C.B.	R.E.N.F.E.	S.N.C.
1.4 — RELEVANT PARTICULARS OF TRACTION SYSTEM	*Contact wires or conductor rails*		29	1.411		Contact wires	Contact wires	Contact
	CONTACT WIRE SYSTEM	*Cables and wires*	30	1.412		*a*) 1 main catenary *b*) 1 auxiliary catenary *c*) 2 contact wires	*a*) 1 catenary *b*) 2 contact wires	*a*) 1 mai catena *b*) 1 aux catena *c*) 2 con wires
		Material	31	1.412		*a*) bronze *b*) copper *c*) copper	*a*) copper *b*) copper	*a*) bronz *b*) coppe *c*) coppe
		Section	32	1.412	mm^2	*a*) 94 *b*) 104 *c*) 2 × 100	*a*) 153 *b*) 2 × 107	*a*) 116.2 *b*) 104 *c*) 2 × 1
		Equivalent copper section . .	33	1.412	mm^2	*a*) 67 *b*) 104 *c*) 200	*a*) 153 *b*) 214	*a*) 88 *b*) 102 *c*) 214
		Height above rail level . . .	34	1.412	m	*a*) 6.95 *b*) 5.30 *c*) 5.10	*a*) 6.54 *b*) 5.31	*a*) 7.25 *b*) ...... *c*) 5.75
		Mean spacing of supports .	35	1.412	m		60	
	Nominal voltage at substations output		36	1.431	V	3 300 3 200 ÷ 3 450	3 300	1 50
	Mean voltage at motive power unit		37	1.432	V	2 900	3 000	1 3
	Minimum voltage at motive power unit		38	1.433	V	2 000	2 650	1 00
	Sectioning points between substations		39	1.441-2		One at mid-point with circuit breakers (10)	At intervals of 7 km and in the stations	N
	With neutral zone?		40	1.441-2		No	Yes	
	With facilities for parallel connection of both tracks		41	1.441-2		Yes (10)	Yes	

(10) Each sectioning point is equipped with one bus bar only, and feeders with circuit breakers as in a substation; the tracks are theref parallel-connected at a sectioning point.

(11) There is also a reinforced contact wire system, with one main catenary (116.2 mm^2, bronze), one auxilary catenary (143.14 mm^2, c two contact wires (2 × 150 mm^2, copper).

. **Electrifications.**

F.S.	P.K.P.	J.D.Z.	R.A.T.P.	ALGERIAN RAILWAYS	MOROCCAN RAILWAYS	D.B.	N.S.
ntact wir.	Contact wir.	Contact wir.	Cond. rails	Contact wires	Contact wires	Conduct. rails	Contact wires
catenary 2 contact wires	*a*) 1 catenary *b*) 2 contact wires			*a*) 1 catenary *b*) 2 contact wires			*a*) 1 catenary *b*) 2 contact wires
copper copper				*a*) steel *b*) copper			
120 2 × 100				*a*) 120 *b*) 2 × 107			
120 200				*b*) 214			
6.40 5	*a*) 6.90 *b*) 5.60			*b*) 6			*a*) 8.60 *b*) 5.50
50		60		60 max.			
3 400 00 ÷ 3 600	3 300 ...... ÷ 3 800	3 400	600 570 ÷ 640	3 000	3 300	1 200 ± 10%	1 500 1 500 ÷ 1 800
3 000	3 000	3 000	600	3 000	3 000	1 000	1 350
2 700	2 100	2 000	420	1 050	2 100	800	1 200
f each station	Yes, one at mid-point, with circuit breakers (10)			Yes (12)		Yes	Yes
Yes	No			No	Yes	Yes	No
Yes	Yes (10)		Yes, with isolators		Yes	Yes	Yes

here is a feeder which follows the contact wire and is connected to the catenary at different points.

			QUESTION	Con-secut. No.	Ques-tion No.	Units of measure-ment	S.N.C.B.	R.E.N.F.E.	S.N.C
1.4 — RELEVANT PARTICULARS OF THE TRACTION SYSTEM	SUBSTATION SPACING		*Mean*	42	1.444	km	34	35	
			Minimum	43	1.444	km			8
			Maximum	44	1.444	km	44		20
			Maximum under emegenrcy conditions	45	1.444	km	75	70	(13)
	Continuous rating of the motive power units at mean voltage . .			46	1.45	A/ms	Locomotives: 310 Amps multiple-unit stock 110 Amps (16)	(17) 750 A	CC 7 10 2 300 A BB 8 10 1 600 A BB 9 10 2 700 A BB 9 20 2 800 A BB 9 400 1 600 Am
	VOLTAGES INDUCED IN THE EVENT OF SHORT-CIRCUIT		*Tests of voltage induced in the event of short-circuit*	47	1.472		Yes	No	Yes
			On cables or overhead lines	48	1.472		cable voltage between wire and lead sheath		
		Current gradient — initial rise	*During the tests* .	49	1.472	A/ms	100 ÷ 300		200 ÷
			Calculated	50	1.472	A/ms			
		Current gradient — rate of fall on disconnection	*During the tests* .	51	1.473	A/ms	Less steep than initial rise		Less s than init
			Calculated	52	1.473	A/ms			
			Induced voltages measured	53	1.48	V/km / A/ms	0.12		
	SOIL RESISTIVITY		*Resistivity values*	54	1.48	ohm. m			10 ÷ 2
			Measurements carried out by the railways	55	1.48		No	No	Ye
			Measuring methods used . .	56	1.48				— phase impe — zero- ce imp — induc volta

(13) The breakdown of one substation may have traffic repercussions.

(14) The initial rate of rise is calculated as the ratio of the voltage and the total inductivity of the circuit, using the value of 1.4-1.5 mH/K loop formed by contact wire and soil. This calculation is corroborated by measurements.

(15) Values relating to the zone in which the induced voltage has been measured.

(16) Values relating to each motor.

(17) Values relating to the whole unit.

C. Electrifications.

F.S.	P.K.P.	J.D.Z.	R.A.T.P.	ALGERIAN RAILWAYS	MOROCCAN RAILWAYS	D.B.	N.S.
40	20	35		57	60	5	18.8
30					18		
60	25	46	4.84	80.5	85	8.4	24
			7.8	106	151	14.8	48
	265 ÷ 365 Amps (16)	Bo Bo Bo : 3 × 200 Amps Bo Bo : 2 × 280 Amps	440 Amps 220 Amps 448 Amps 500 Amps 600 Amps (17)	6 AE : 720 Amps 6 BE : 945 Amps (17)	E 500 : 300 Amps E 200 : 400 Amps E 600 : 400 Amps E 700 : 500 Amps E 800 : 885 Amps (17)	ET 171 : 440 Amps (17)	Multiple-unit stock : 400-800 Amps (17) Locomotives ABA 1 : 2240 Amps BB : 1 560 Amps CC : 1 755 Amps CC : 2 340 Amps
Yes	No	No	No	No	No		
Overhead line							
20 ÷ 50							
V/L (14)	150 ÷ 550						
ar. depend. on circuit nd circuit breaker							
	Less steep than init. rise						
0.3	(19), (18)						
) ÷ 50 (15)	40 ÷ 300	$10^3 \div 10^5$				20 ÷ 100	
Yes	Yes	No	No				
electrodes	Potential soundings in 3 Y arrangem.						

No measurements have been carried out, but the calculations have been based on the « UIC Draft 1957 », using an equivalent frequency of 24 c/s.
The interference produced by the harmonics on the contact wire are also calculated by using the CCIF and CCIT formulas and adopting the following telephone form factors of the voltage :

— 1.5 % in the case of 12-phase rectifiers without filters;
— 3 % in the case of 6-phase rectifiers without filters;
— 0.5 % in the same cases, but with filters.

The disturbances have only been calculated for overhead telecommunication lines.

TABLE 5. — PA

		QUESTION	Con-secut. No.	Ques-tion No.	Units of measure-ment	S.N.C.B.	R.E.N.F.E.	S.N.C.
1.5 — COMPENSATING FACTORS	RAILS	*Track gauge*	57	1.51	m	1.445		1.435
		Distance between centre lines of adjacent tracks	58	1.51	m	3.48	3.68	3.50
		Number of rails used for the return current	59	1.511		2	2	2 (21
		Distance of bonds between the rails of the same track . .	60	1.511	m	125 (20)	500	
		Distance of bonds between the rails of adjacent tracks . .	61	1.511	m	250 (20)	500	
		Weight of new rails	62	1.512	kg/m	49.8	45	Several t up to 62
		Cross-sectional area of rails.	63	1.512	mm²	6 345		
	BONDS	*Material*	64	1.513		Copper	Copper and steel	*a)* De-oxi sed c *b)* Coppe
		Fastening method	65	1.513		Soldering	Electric welding	*a)* Weldi *b)* Drive
		Dimensions	66	1.513	mm²	2 × 50	51.20 (copper) 87.78 (steel)	*a)* 2 × 5 *b)* 181.6
		Equivalent length of rail . . .	67	1.513	m	1	3	2

(20) Track-circuited lines are equipped with impedance bonds which, on double-track lines, are connected by transverse equipotential bo

(21) With single-rail track circuits, which are of exceptional character, it is sometimes necessary to duplicate the single return path by an

. Electrifications.

F.S.	P.K.P.	J.D.Z.	R.A.T.P.	ALGERIAN RAILWAYS	MOROCCAN RAILWAYS	D.B.	N.S.
1.435	1.435	1.435	1.435	1.435	1.44	1.435	1.435
3.60	4 ÷ 4.9	3.50	2.90	3.50	3.57	3.5 ÷ 4	3.60 ÷ 4
2 (22)	2	2	2	2	2	All rails	2
180 (23)		180	Impedance bonds every 300 m	250	120	150	
			Equipotential bonds 450		120	300	
	a) 49.1 *b)* 42.5	42	52	46	46.3	49.43	46.9
	a) 6 248 *b)* 5 424	5 767			5 906	6 297	5 975
Copper		Copper	Copper	Copper	Copper	Copper	Copper
Welding		Welding		Welding	Welding	*a)* Old type : plugs *b)* New type : welded	
		50		2 × 53	107	*a)* 120 *b)* 150	
3 ÷ 5	1.5	3.12	1.5 ÷ 5	1		*a)* 2 ÷ 10 *b)* 0.5	2

In track-circuited stations one rail only.

These bonds do not exist on lines with automatic block.

TABLE 6. — PA

	QUESTION	*Con-secut. No.*	*Ques-tion No.*	*Units of measure-ment*	*S.N.C.B.*	*R.E.N.F.E.*	*S.N.C*
1.5 — COMPENSATING FACTORS	*SUPPORTS* — *Material*	68	1.514		Steel	Steel	Steel
	SUPPORTS — *Earthing devices* — *Without automatic block*	69	1.514		No	Earth plate	Connect to the r
	SUPPORTS — *Earthing devices* — *With automatic block*	70	1.514		No		Earth electro
	Earthing of the rails	71	1.515		No to avoid corrosion	With earth shafts at the substations	No
	Impedance of a rail at 50 c/s	72	1.516	ohm/km	0.75/70°		0.50/8
	Impedance of a rail at 800 c/s	73	1.516	ohm/km			5.70/8
	Insulation resistivity of a rail in relation to the earth	74	1.517	ohm.km	No difficulties for the track circuit		1 ÷ 2
	Voltage betw. rail and earth — *in normal operation*	75	1.518	V	2 ÷ 40		
	Voltage betw. rail and earth — *in the event of a short-circuit*	76	1.518		100 V with overload		Value compat with sa
	Impedance of the contact wire-rail loop at 50 c/s	77	1.519	ohm/km	1 cat. - 1 track 0.37/81° L=1.15 mH/km		1 cat. - 1 0.48/7
	Return conductors	78	1.531		No	On lines with heavy traffic, 100 mm² copper wire in parallel with the rail	
	Earth wire connecting the supporting structures	79	1.541		Yes, all supports	No	
	Other devices to reduce interference	80	1.542		No	No	

(24) There is a connection to the rails at every fourth support, and an earth connection at every seventh support; all the supporting struc connected by an earth wire.

. Electrifications.

F.S.	*P.K.P.*	*J.D.Z.*	*R.A.T.P.*	*ALGERIAN RAILWAYS*	*MOROCCAN RAILWAYS*	*D.B.*	*N.S.*
Steel	Steel	Steel		Steel	Steel		Steel
onnect. to e rails at 3rd mast	Connections to the rails	Connec. to the rails and to earth el. (24)		Connections to the rails	Individual earth plate		Connections to the rails
Earth lectrodes							Connections to the rails with discharge gaps
No		No	No	No	At the substations only		No
esistance : 07 ÷ 0.17			0.70/70°				
1 ÷ 4							
30 ÷ + 70		3 ÷ 4	15 ÷ 20	15	15	SEE PART *B*	30 - 80
Not measured							
at.- 1 track 0.48/80° L = 1.15 mH/km				L = 1 mH/km			2 cat.- 2 tracks R = 0.023Ω/km L = 0.63 mH/km
No		No	No	No			No
es, every d support		Yes, all supports	No	No	Yes, every 3rd support		No
No		No	No	No	No		No

TABLE 7. — PA

	QUESTION	Con-secut. No.	Ques-tion No.	Units of measure-ment	S.N.C.F.	LOWER-CON KATANGA
1.1 — POWER SUPPLY — H.T. NETWORK	*Does the H.T. network belong to the railways?*	1			SEE PART *A*	No
	Number of phases	2	1.121			3
	Frequency	3		c/s		50
	Rated voltages and permitted variations	4	1.122	kV		110 ± 5 %
	Traction load in per cent of total load	5	1.123	%		2.02 %
	Are the H.T. lines systematically parallel to the railway lines? .	6	1.124			Yes
	Minimum distance of parallel H.T, lines from track	7	1.124	m		100
	Mean distance of parallel H.T. lines from track	8	1.124	m		250
	Connections of neutral points . . .	9	1.125			Solidly earth
	Selective distance protection . . .	10	1.126			Yes
	Maximum time for disconnecting a fault	11	1.126	sec		0.1 (1)
	Automatic reclosure	12	1.126			Yes, three-pha
	Phase transpositions	13	1.127			Yes

(1) For the first disconnection.

Electrifications.

S.B.B.	D.B.	RHAETIAN RAILWAY	F.S.	Ö.B.B.
Yes	Yes	Yes		Yes
1	1	1		1
16 2/3	16 2/3	16 2/3		16 2/3
33 - 66 - 132 /34-62/68-126/144	110 ± 10%	11 8.5/12		55 - 110 — 5 + 12%
100%	100%	100%		100%
rtly on the same porting structures s the catenary; otherwise on ependent alignm.	No	Yes		in some instances
				15
		2.5 ÷ 3		400
	Earthed through reactance			55 kV: neutral point solidly earthed; 110 kV: earthed through reactance
s, on the 66 kV nd 132 kV lines	Yes	Yes		Yes
0.65 (1)	7.5			0.15
No	No	No		No
				Yes

TABLE 8. — PA

		QUESTION	Con-secut. No.	Ques-tion No.	Units of measure-ment	S.N.C.F.	LOWER-CONG KATANGA
1.2 — SUBSTATIONS		*Transformers in Scott connection*	14	1.22		Yes, partly	No
		Amplitude of the current harmonics in the substation input	15	1.24			
		Short-circuit level at the substation input	16	1.25	MVA	100 - 2 500	
	FEEDERS	*Type of protective relay* . .	17	1.26		Maximum relay and admittance relay for distant faults	
		Automatic reclosure. . . .	18	1.262		Yes, once after 15 sec	Yes
		Earth tests	19	1.262		No	Yes
		Number of reclosures . .	20	1.262			3
		Interval between reclosures	21	1.262	sec		40
		Time for disconnecting a fault	22	1.261	sec	0.12 max	0.3 ÷ 6 (2)
1.3 — TRACTION SYSTEM		*Nominal voltage of traction system*	23	1.3	V	25 000	25 000
		Number of phases	24	1.3		1	1
		Frequency	25	1.3	c/s	50	50
	LENGTH OF ELECTRIFIED LINES	*single-track*	26	1.31	km	260	527
		double-track	27	1.32	km	1 435	
		total	28	1.33	km	3 130	527

(2) Range of tripping time adjustment.

Electrifications.

S.B.B.	*D.B.*	*RHAETIAN RAILWAY*	*F.S.*	*Ö.B.B.*
3rd harmonic 3 %	3rd harm. 8.9 - 13.1 % 5th harm. 5.1 - 9.2 %			
3 kV : 25 - 50 6 kV : 100 - 260 2 kV : 180 - 260	max. 1 100			
Overload relay	Impedance relay or time lag maximum relay			Overload relay
Yes	No, tests will be carried out			No
Yes				Yes
2				
0.1	0.09 ÷ 0.15			0.09 ÷ 0.15
15 000	15 000	11 000	3 400	15 000
1	1	1	3	1
16 2/3	16 2/3	16 2/3	16 2/3	16 2/3
1 648	336	270	737	886
1 272	2 711	7	587	890
4 192	5 758	284	1 324	2 666

TABLE 9. — PA

			QUESTION	Con-secut. No.	Ques-tion No.	Units of measure-ment	S.N.C.F.	LOWER-CON KATANGA
1.4 — RELEVANT PARTICULARS OF TRACTION SYSTEM			*Contact wires or conductor rails* .	29	1.411		Contact wires	Contact wires
	CONTACT WIRE SYSTEM		*Cables and wires*	30	1.412		*a)* 1 catenary *b)* 1 contact wire	*a)* 1 catenary *b)* 1 contact wire
			Material	31	1.412		*a)* bronze *b)* copper	
			Section	32	1.412	mm^2	*a)* 65.38 *b)* 107	
			Equivalent copper section . .	33	1.412	mm^2	*a)* 40 *b)* 107	
			Height about rail level . . .	34	1.412	m	*a)* 7.15 *b)* 5.75	*b)* 5.50
			Mean spacing of supports . .	35	1.412	m		60
			Nominal voltage and frequency at substation output, and their variations	36	1.42 1.43	V	25 000 at full load cos φ = 0.8	25 000 25 500 max
					1.431	c/s	50 ± 1 %	50 ± 0.2
			Mean voltage at motive power unit	37	1.432	V	22 500	22 000
			Minimum voltage at motive power unit	38	1.433	V	19 000	18 500
	SUBSTATION SPACING		*Mean*	39	1.444	km		75
			Minimum	40	1.444	km	40	
			Maximum	41	1.444	km	90	
			Maximum under emergency conditions	42	1.444	km	140 (3)	150

(3) With repercussions on traffic, though not to the same extent as with D.C.

ectrifications.

S.B.B.	*D.B.*	*RHAETIAN RAILWAY*	*F.S.*	*Ö.B.B.*
tact wires	Contact wires	Contact wires		Contact wires
atenary ontact wire	*a)* 1 catenary *b)* 1 contact wire	*a)* 1 catenary *b)* 1 contact wire		*a)* 1 catenary *b)* 1 contact wire
per	*b)* copper			
0 0	*b)* 5.75	*a)* 7.20 *b)* 5.40		*b)* 5.75
50 ÷ 60				⩽ 75
15 000 ± 10%	15 000 + 20% — 10%	11 000 8 500 ÷ 12 000		15 000 ± 20%
+ 2.5% - 2.1%	16 2/3 ± 3%	16 2/3; 15 1/2 ÷ 17 1/2		16 2/3 + 5% - 10%
00 ÷ 15 000	15 000	11 000		
12 000	12 500	8 500		
35 - 40	60			50
14				
72	105.6			
	165.8			

TABLE 10. — PA

	QUESTION		Con-secut. No.	Ques-tion No.	Units of measure-ment	S.N.C.F.	LOWER-CON KATANGA
1.4 — RELEVANT PARTICULARS OF TRACTION SYSTEM	*Continuous rating of the motive power units at mean voltage . .*		43	1.45	A	BB 12 000 : 165 BB 13 000 : 145 BB 14 000 : 155 BB 14 000 : 95 BB 16 000 : 120 BB 16 000 : 160	— BCK 2 100 : 4 · BCK 2 200 : 4 with A.C. mot — BCK 2 300 : 4 with ignitron — BCK 2 400 : 4 with silicon re
	Types of motors used		44	1.451		Ignitrons	— A.C. motors — ignitrons — silicon
	WITH D.C. MOTORS	*Reactors a. filters adopted*	45	1.452		Smoothing coil only	Smoothing coil only
		Amplitude of A.C. side harmonics	46	1.453		R.m.s. value of first 17 harmonics 25 ÷ 26 %	
		Ripple coefficient	47	1.453		< 30 %	30 %
	Short-circuit current used for calculating the risk of danger . . .		48	1.471		Calculated by evaluating, the circuit impedances (4)	
	SOIL RESISTIVITY	*Resistivity values . . . .*	49	1.48	ohm.m	SEE PART *A*	Greatly varia
		Measurements carried out by the railways	50	1.48			No
		Measuring methods used .	51	1.48			

(4) The values obtained depend mainly on the power of the substation and on the distance of the short-circuit point.
(5) For the four dual-frequency excitron locomotives.

. **Electrifications.**

S.B.B.	D.B.	RHAETIAN RAILWAY	F.S.	Ö.B.B.
anging from 100 to 350 for the different motive power units	E 16-:210 - E 17:175 E 18-:225 - E 44:145 E 93-:175 - E 94:240 E 10-:280 - E 40:280 E 41-:175 - E 50:340 ET 25-: 71 - ET 26:34 ET 30-:126 - ET 56:70			1 010 : 220 1 110 : 220 1 018 : 210 1 020 : 200 1 040 : 135 4 030 : 60
A.C. motors; only four dual-quency locomotives with excitrons	A.C. motors			A.C. motors
moothing coil (5)				
(6)	Curves as a function of the distance from the substation : 1 kA at 70 km, 8-12 kA at the output			1.5 ÷ 2 kA at the mid-point between two sub-stations; 8 ÷ 10 kA at the substation output
50 - 50 000	20 - 100			Greatly variable
No				

he protective devices have been provided, without calculations, for induced voltages of 2 000 V. Subsequent calculations have yielded results hich remained, in all cases, below 2 000 V.

TABLE 11. — PA

		QUESTION	Con-secut. No.	Ques-tion No.	Units of measure-ment	S.N.C.F.	LOWER-CONC KATANGA
1.5 — COMPENSATING FACTORS	RAILS	*Track gauge*	52	1.51	m	SEE PART *A*	1.067
		Distance between the rails of adjacent tracks.	53	1.51	m		
		Number of rails used for the return current	54	1.511		2 (7)	2
		Distance of bonds between the rails of the same track . .	55	1.511	m	330	240 (every fourth sup
		Distance of bonds between the rails of adjacent tracks . .	56	1.511	m		
		Weight of new rails	57	1.512	kg/m	Several types	40
		Cross-sectional area of rails.	58	1.512	mm²	Several types	
	BONDS	*Material*	59	1.513		*a*) de-oxidulised copper *b*) copper	Copper
		Fastening method	60	1.513		*a*) welding (8) *b*) drive pins	Welding
		Dimensions	61	1.513	mm²	*a*) 53.48 or 32.41 *b*) 75	50
		Equivalent length of rail . .	62	1.513	m	< 2	
	SUPPORTS	*Material*	63	1.514		Steel	Steel
		Earthing devices — *Without automatic block*	64	1.514		Connected to the rails	Connections to th and earth electro every fourth su
		Earthing devices — *With automatic block*	65	1.514		One earth cable connecting the supports, and one earth connec. every 1000 metres	

(7) One single rail would suffice, but the return is ensured by both rails because of the impedance bonds of the track circuits required for t tion of broken rails.
(8) Drive pin connections are used where welded connections are not practicable.

Electrifications.

S.B.B.	*D.B.*	*RHAETIAN RAILWAY*	*F.S.*	*Ö.B.B.*
1.435	1.435	1.00		1.435
3.60	3.5 - 4	3.60		4
2 (9)	All rails	2		All rails
	150			
	300			
.9 - 35.9 - 54.43	49.43	25 - 27 - 30.1 - 36		49
50 - 4 580 - 6 930	6 297	3 200/3 462/3 860/4 580		
Copper	Copper (10)	Copper		Not normally used
Welding	Welding	Welding		
35	35			
	—			
Steel	Steel	Steel		Concrete or steel
nected to the rails	Connections to the rails	Earth electrodes		Connections to the rails

/ith the exception of those sections with track circuits which are generally of the single-rail type.
onds are only used where there are track circuits.

TABLE 12. — PA

	QUESTION		Con-secut. No.	Ques-tion No.	Units of measure-ment	S.N.C.F.	LOWER-CON KATANGA
1.5 — COMPENSATING FACTORS	*Earthing of the rails*		66	1.515		No	Yes, at every fo support
	Impedance of a rail at 50 c/s		67	1.516	ohm/km	SEE PART *A*	Not measure
	Impedance of a rail at 800 c/s		68	1.516	ohm/km		Not measure
	Leakage resistivity of one rail		69	1.517	ohm.km		> 10
	VOLTAGE BETWEEN RAIL AND EARTH	*in normal operation*	70	1.518	V		12 - 75
		in the event of a short-circuit	71	1.518	V		Not measure
	Impedance of the contact wire-rail loop at fundamental frequency		72	1.519	ohm/km		0.25 + j 0.56 calc 0.24 + j 0.44 me
	Booster transformers		73	1.521		No	No
	Return conductors		74	1.531			No
	Eearth wires connecting the supporting structures		75	1.541		See No. 65	
	Other devices to reduce interference		76	1.542		No	No

. Electrifications.

S.B.B.	*D.B.*	*RHAETIAN RAILWAY*	*F.S.*	*Ö.B.B.*
No	No	Yes, earth electrodes		No
Not measured				
Not measured				
	1 - 4			1 - 10
R1 with R = 0.15 Ω with suitable and dry ballast	3 - 8			2 - 20
				Not measured
1 cat. - 1 track 0.265/46°	2 cat. - 2 tracks $0.08 + j\ 0.09$ 1 cat. - 2 tracks $0.15 + j\ 0.14$ 1 cat. - 1 track $0.15 + j\ 0.16$			0.2 - 0.25
No	No	No		No
No	No			No
No	No			
No	No	The telecommunication lines have a minimum distance of 20 m		No

1.1. Power supply.

1.11 to 1.123. — In electric traction, the substations are generally fed by public three-phase supply networks which also supply other consumers. The traction load represents a varying percentage, ranging from 2 to 50 %, of the total load. It goes without saying that, on each individual line, the traction load percentage of the total load may differ very considerably.

A complete exception must, of course, be made in the case of single-phase A.C. 16 2/3 c/s electrification systems (*C.F.F., D.B., Ö.B.B.*), which are fed by railway-owned single-phase 16 2/3 c/s H.T. networks feeding the traction substations only.

Special exceptions are the *F.S.* who have their own three-phase 50 c/s H.T. network and, to some extent, *R.E.N.F.E.*, the *Polish State Railways* (*P.K.P.*), the *Jugoslav Railways* (*J.D.Z.*), the *Netherlands Railways* (*N.S.*), and the *German Federal Railways* (*D.B.*) for D.C. traction who possess medium-tension feeder lines. The rated voltages differ greatly (from 10 to 150 kV), depending on the size of the system and the length of the lines. The admissible voltage variations do not normally exceed 5 to 10 %. Where greater voltage variations occur, use is normally made of tap changing under load on the substation transformers.

1.124. — With most networks, the alignment of the H.T. lines is independent of the railway line. Only a few systems have a number of H.T. lines which run parallel to the railway lines (see Tables).

1.125, 1.126, 1.127. — The method of connecting the neutral points varies greatly. But only few systems are still working with insulated neutral point, and there is a clear preference for connecting it directly to earth.

With most H.T. and M.T. lines, remote selective protection gear ensuring a disconnection of earth faults within very short periods of time has already been adopted, or its adoption is envisaged in the near future. In contrast, the adoption of devices for the automatic reclosure of current is very limited (being virtually confined to France, with slow single-phase and three-phase reclosure; the latter is the only one to be used on M.T. lines).

The lines are generally transposed; on certain systems, the transposition is limited to long-distance lines (*R.E.N.F.E., J.D.Z.*), or not used at all (*S.N.C.B.*).

1.2. Types of substations.

A) D.C. ELECTRIFICATIONS.

1.2, 1.231. — Connection diagrams of substations.

With some rare exceptions of old substations with rotary converter sets, all the substations are equipped with mercury vapour transformer-rectifier sets. All these sets are six-phase but differ from each other as regards the arrangements of the secondary transformer winding and the number of anodes per rectifier.

The replies received are not sufficiently detailed for the preparation of a comprehensive report on this subject. In any case, a distinction can be made between :

a) transformers for six-anode feeds :

— secondary star/star connected, the neutrals being connected by an absorption coil (fig. 1) (*S.N.C.B., S.N.C.F., R.E.N.F.E., N.S.*, etc.);

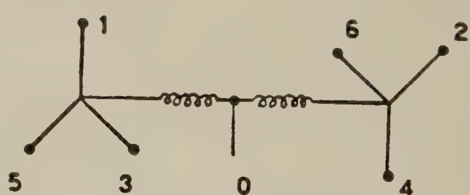


Fig. 1.

— secondary as above, but with the neutrals directly connected (fig. 2) (*Moroccan Railways — C.F.M.*);

Fig. 2.

— secondary triple-star connected (fig. 3) (*F.S.*);

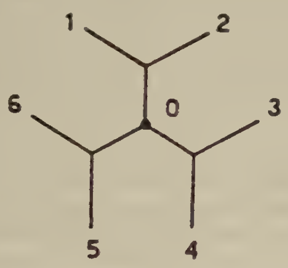


Fig. 3.

b) transformers for twelve-anode feeds:

— secondary as above, but with double windings or anodic dividers.

Apart from a few cases of single-anode (*R.E.N.F.E., C.F.M.*) or three-anode (*R.E.N.F.E.*) rectifiers, all the rectifiers have six or twelve anodes.

In all cases, the grids are exclusively used as a protection against arc-backs and overloads. A single exception is provided by the *S.N.C.F.* rectifiers which are equipped with control grids delaying the ignition of the anodes at low load and permitting a natural commutation at the rated or higher loads.

1.232. — Ripple reducers.

The substations of *R.E.N.F.E.*, the *Algerian* and *Moroccan Railways, P.K.P.* and *J.D.Z.* are equipped with filters of the resonant type for the harmonics of the 6th, 12th, 18th and 24th order, and those of *F.S.* with filters of the aperiodic type.

S.N.C.F., S.N.C.B., N.S. and *D.B.* do not use filters, but all their signalling and telecommunication circuits are cabled.

1.24. — Magnitude of the harmonics in the substations input.

The only measurements have been carried out by the *S.N.C.F.* where the effective value of the first 17 harmonics was found to attain 21 to 23.5 %.

1.25. — Short-circuit level at the substation input.

This level obviously depends on the extent of the H.T. network and on the output of the power stations connected to it; it also varie with the position of the substation in relation to the network.

The values are shown in the Tables.

1.26, 1.261. — Feeder protection.

Feeder protection is ensured by ultrahigh-speed circuit breakers; in some cases, these are equipped with additional tripping devices depending on the rate of rise of current (*S.N.C.B.*).

The time required for disconnecting a fault also depends on the distance of the fault itself; the values reported range from 5 to 100 millisec. One may however be inclined to think that the very short times indicated in some of the replies (5 to 10 millisec) merely comprise the action and mechanical tripping time of the circuit breaker, and not the duration of the arc.

1.262. — Reclosure. — Earth tests.

In general, automatic reclosure is used, preceded by automatic earth tests which are repeated up to three or five times at intervals of 10 to 30 sec. The *S.N.C.B.*

resort to automatic reclosing without earth tests after an interval which differs, for each feeder of the same substation, from 1 to 10 sec.

B) A.C. ELECTRIFICATIONS.

1.2, 1.222. — Substations connections. — Arrangements for reducing load unbalance.

With single-phase 16 2/3 c/s systems, the problem of unbalance does not exist, as the substations are fed by a single-phase H.T. network connected to single-phase alternators.

With single-phase 50 c/s systems fed from the public supply network, Scott transformers (*S.N.C.F.*) were used at the outset. With more recent installations however (*S.N.C.F., Lower-Congo-Katanga*), load balancing measures are confined to a suitable permutation of the connection of the different substations to the phases of the grid, a measure which has been found satisfactory in practice. It should be remembered that the magnitude of the unbalance greatly depends on the proportion of the traction loads and the total load on the T.H. line or grid; in many cases, the degree of unbalance will therefore be negligible in practice.

1.24. — Magnitude of the harmonics in the substation input.

For single-phase 16 2/3 c/s systems, data have been supplied by *D.B.* (3rd harmonic 8.9 to 13.1 %; 5th harmonic 5.1 to 9.2 %) and by *C.F.F.* (3rd harmonic 3 %).

1.25. — Short-circuit level at the substation input.

See the Tables.

1.26, 1.261, 1.262. — Feeder protection.

In general, maximum current relays are used. *S.N.C.F.* and *D.B.* also use admittance or impedance type protections (especially for remote faults).

With the exception of *D.B.*, automatic reclosure has been adopted, either with earth tests (*C.F.F., Lower-Congo-Katanga*) or without earth tests (*S.N.C.F.*).

For disconnection times, see the Tables.

1.3. Traction systems.

The numerical data relating to the length of electrified single-track and double-track lines are shown in the Tables.

1.4. Relevant particulars of the traction system.

1.41 to 1.451. — These are data and descriptive replies concerning the arrangement of the catenary system and supply particulars, the spacing of substations, the rating of the motive power units, etc., which can be appreciated from the Tables.

It will be noted that, for the same type of electrification system, there are no substantial differences in these respects as between one installation and another.

1.452-1.453. — Current distortion in the case of electric traction with rectifier locomotives.

In no case are special filters adopted, but merely smoothing coils which are series-connected with the motors, and the ripple coefficient does not exceed 30 %. The magnitude of the harmonics on the A.C. side has only been measured by the *S.N.C.F.* where the effective value of the first 17 harmonics was found to attain 25 to 26 %.

1.46, 1.471.

A) *Values of normal and maximum (short-circuit) current used for calculating the interference affecting the telecommunication and signalling circuits with A.C. electrifications.*

The values used are effective values based on calculation or measurements,

taking all the relevant parameters into account (*S.N.C.F., D.B., and Ö.B.B.*). The Swiss Federal Railways originally rated their protective devices for induced voltages of 2 000 V without carrying out calculations; subsequent calculations have in all cases, yielded results below 2 000 V.

B) *Calculation of disturbing effects on telecommunication and signalling circuits with D.C. electrifications.*

The *Polish State Railways* (*P.K.P.*) are using the C.C.I.F. and C.C.I.T. formulas by adopting telephone form factor values of 1.5, 3 and 0.5 %, respectively, for 12-phase rectifiers without filter, 6-phase rectifiers without filter, and for both types with filter.

D.B. also use the C.C.I.F. and C.C.I.T. formulas by adopting as telephone form factor the value of 3 %.

1.472-1.473. — Values of the maximum rate of rise of current used for calculating the dangers to telecommunication and signalling circuits with D.C. electrification systems. — Tests of voltages induced under short-circuit conditions.

Tests have been carried out by *S.N.C.F.*, *S.N.C.B.* and *F.S.* The initial rates of rise (which naturally depend on the distance between the short-circuit point and the substation and on the characteristics of the circuit formed by the feeder sets, catenary and rails) were found to range from 20 to 500 A per millisec, and can of course be calculated as the ratio of the voltage and the total inductance of the circuit concerned. As regards the rates of fall during the opening of the circuit, the tests carried out by *S.N.C.F.* and *S.N.C.B.* have yielded lower values than during the initial stages so that these are not being taken into account. *F.S.* have found, on the strength of their own tests, that the rate of fall greatly depends on the type of circuit breaker; with ultra-high-speed circuit breakers, where the arc is suppressed very energetically and extinguished very rapidly, the rate of fall was found to be very high (Plate I). It may be added, however, that these circuit breakers are very difficult to use in any case as they also entail high and dangerous overvoltages on the traction installations themselves.

As regards the calculation of the induced voltages, it is worth recalling the method of equivalent frequency suggested by the *S.N.C.F.* on the strength of their tests, and confirmed by the tests carried out by *F.S.* This method is used by the *Polish State Railways* (*P.K.P.*).

1.48. — Resistivity of the soil.

No Administration has carried out systematic tests of the resistivity of the soil along its electrified lines. Certain measurements have merely been carried out in the zone where the interference tests took place (*S.N.C.F., P.K.P., F.S.*) in order to ascertain the resistivity values to be introduced into the calculations. For these tests, the *S.N.C.F.* have used the methods of measuring the impedance between phase and earth, measuring the zero-sequence impedance and measuring the voltage induced in a telecommunications circuit. *F.S.* have used the conventional four-electrode method, whilst *P.K.P.* have used a new method known as « potential sounding with the 3 Y arrangement », and mainly designed for geological research. This method, like the conventional four-electrode or Wenner methods, is based on measuring the differences in the potential between two electrodes caused on the surface of the soil by currents introduced into the soil by means of other electrodes. But the arrangement of the electrodes is completely different; in particular, the direction in which the potentials are measured is at right angles to the direction in which the current is introduced. This method has the advantage of permitting a large depth range with a relatively small electrode spacing, and the easy determination of the depth of the different zones of resistivity.

D.B. also remark that the equipment based on the four-electrode method is not sensitive enough for resistivity research in depth, and that they will therefore carry out tests with other methods.

It can be stated that the question of measuring the resistivity of the soil still represents a fairly difficult problem which is still the subject of various studies.

These difficulties may be ascribed to the fact that the resistivity value (or its inverse, viz., the value of conductivity) which must be introduced into the calculations, is the value encountered in fairly extensive geological formations containing, to a greater or lesser degree, water and saline solutions which one seeks to determine by carrying out measurements on the soil surface. And, as the depth of penetration is, in its turn, a function of the frequency, a variation of the frequency will cause an apparent variation in these values.

According to Dr. KLEWE, the depth of penetration of the currents can be expressed by a term of the type $(\sigma f)^{-1/2}$ (if σ is the conductivity of the soil). Therefore, whilst the direct currents spread out fairly widely, the alternating currents tend to affect a layer of more and more reduced thickness as and when the frequency is increased, and the return current approaches the primary current more and more.

It may be (and this is also the opinion expressed by Dr. KLEWE) that the best method of determining σ or its inverse value would consist in actually measuring the mutual inductance between two parallel lines, which would permit the determination of the unknown σ after introducing the known and measured values in the Pollaczek formula which yields the value of M. The measurements would have to be carried out within a sufficiently wide range of frequencies.

The WENNER method mentioned above consists in measuring the current I discharged by a current supply connected to two electrodes 1 and 4, and measuring the difference in the potential V thereby caused between two electrodes 2 and 3 (*). If a_{ij} is the distance between the points i and j, one obtains :

$$\frac{V}{I} = \frac{1}{2\pi\sigma}\left(\frac{1}{a_{12}} + \frac{1}{a_{34}} - \frac{1}{a_{13}} - \frac{1}{a_{24}}\right).$$

If the points 1, 2, 3, 4 are located on a straight line and there is a constant distance a between two adjacent electrodes, this formula is transformed into the simpler and well-known :

$$\frac{V}{I} = \frac{1}{2\pi\sigma a}$$

It should be remembered that, for depths up to 1 m or so, σ also depends on meteorological conditions, and therefore on the temperature and on the humidity of the soil.

It is also greatly influenced by the presence of conductors buried in, or placed on, the soil such as cables, metal pipes, rails, etc., in the vicinity of the point where the measurements are carried out. The variations caused thereby depend on the position of these conductors relative to the alignment of the four electrodes (two voltage electrodes, two current electrodes) used for the measurements. According to fairly recent research on the subject, this influence is particularly marked where the alignment is parallel.

In view of the importance of these measurements for telecommunications problems, it was recently proposed, at the last C.M.I. meeting at Freiburg im Breisgau, that an atlas of soil resistivity should be compiled. But if the results are to be comparable, it is, first of all, necessary to specify the measuring methods and the precautions to be taken.

It is relevant to draw attention, in this connection, to a recent article by Mr. H. PECH in the periodical : « *Câbles et Transmission* » of July, 1958, entitled : « La mesure de la résistivité des sols pour l'ingénieur des télécommunications » (« The measurement of soil resistivity for the telecommunication engineer »).

(*) The formula is valid whatever is the position of the four electrodes so long as the earth may be envisaged as semi-infinity.

1.5. Compensating factors.

1.51, 1.511, 1.512, 1.513. — Please consult the Tables for particulars concerning the track gauge, the distances between the tracks, the connections between the rails, the cross sections and weights of the rails, and the bonds at the rail joints.

1.514, 1.515, 1.541. — Earthing of supporting structures and rails. — Earth wires connecting the masts.

These are safety measures taken as a precaution against accidents in the event of the supporting structures coming into contact with the catenary voltage. Numerous solutions have been adopted and, in the absence of automatic block working, these can be summarized as follows:

- connections between all the supporting structures and the rails; no earthing plates at the masts; no earth wires connecting the masts with each other (*S.N.C.F., C.F.F., P.K.P., D.B., N.S., Algerian Railways, Ö.B.B.*);
- no connection between masts and rails; no earth wires; precautions confined to earth plates for all masts (*R.E.N.F.E., Rhaetian Railway*);
- no connection between masts and rails; no earthing of the masts; precautions confined to earth wire connecting the masts (*S.N.C.B.*);
- no connection between masts and rails; masts earthed and connected by a wire (*Moroccan Railways*);
- every third or fourth mast connected to the rails and earthed; earth wire (*F.S., J.D.Z.*);
- every third or fourth mast connected to the rails and earthed; no earth wires (*Lower-Congo-Katanga*).

On lines equipped with automatic blocks, connections to the rails are obviously not used. *N.S.* are the only Administration to use such connections by inserting discharge gaps.

Direct earthing of the rails is only reported by the *Rhaetian Railway*, and by the *Moroccan Railways* at the substations.

It can thus be stated that, except when track circuits are used, a connection to the rails is provided on most electrified lines. As it happens, the rail is the safest earth, and a connection with the rails, where such connection is possible, is the best precaution against accidents, also in view of the difficulty of obtaining, with earth plates, a sufficiently low resistance to prevent the appearance of mast-earth voltages dangerous to human life when the mast becomes alive.

With D.C. electrifications, the connection with the rails increases the leakance of the rail to earth, and thus the risk of electrolytic corrosion in the vicinity of the line. It is worth noting that none of the replies mentions the use of discharge gaps in these connections in order to obviate this disadvantage, except the *N.S.* who however, as already mentioned, use these discharge gaps for the connections between masts and rails even on lines with automatic block, a measure which has caused no trouble with the track circuits.

1.516, 1.519. — Impedance of the rail, and impedance of the loop formed by contact line and rail.

Please consult the Tables.

1.517-1.518. — Leakage resistivity and voltage between rail and earth.

Please consult the Tables. The particulars are difficult to compare as they are influenced by many parameters. The maximum values given for the voltage between rail and earth do not exceed 100 V (at normal working).

1.521-1.522.3. — Booster transformers.

No Administration has reported the use of these devices.

1.531. — Return conductors.

R.E.N.F.E. is the only Administration to mention the use, on lines with heavy traffic, of a copper wire of 100 mm² cross section area placed on the traction wire supports and connected to the rail at intervals of 500 m.

1.514-1.55. — Special compensating devices to reduce interference.

No special device has been reported.

CHAPTER II.

COUPLING.

2.1. Resulting interfering effects.

The following is a brief summary of the replies received to the questions in §§ 2.11 to 2.15, inclusive, as regards the interfering effects of the traction currents, taking the compensating or screening factors into account.

2.11-2.12. — The question of the value and the phase angle of the currents in screening conductors (rails, earthed conductors, if any) in relation to the contact wire current is generally encountered on A.C. electrified systems.

Some Administrations have carried out tests and measurements on this subject. In most cases, these measurements are merely concerned with the value (modulus) of these currents, and not with the phase (argument), these items being related to the corresponding items of the current in the contact wire system.

The data received are not numerous. They are as follows :

D.B. — The currents in the running rails related to the current in the contact wire system, and the phase angles of these currents in relation to the same current, with a soil conductivity of 350 μS/cm and for rails of type S. 49, are given in the following Table :

Values of current	*Number of tracks*	
	1 or 2	*More than 2*
a) At a frequency of 16 2/3 c/s :		
Normal current	50 % — 175°	65 % — 175°
Short-circuit current	50 % — 180°	65 % — 180°
b) At a frequency of 800 c/s	50 %	65 %

In the case of lines equipped with conductor rail (third rail) the current in the rails amounts, with one or two tracks, to 30 % of the current in the conductor rail.

C.F.F. — For double track lines with two 107 mm² copper contact wires; rails of 58.5 cm² cross section, a telecommunication cable about 2.3 m distant from the centre line of the track, diameter over the lead 45 mm, lead thickness of 3 mm, the following data are quoted :

Load current	A	88	176	264	408
Current in the four rails	A	50	116	157	245.5
Phase angle		174°	179°	179°	—
Current in cable sheath	A	2.3	4.0	9.0	19.4
Phase angle		136°	139°	135°	
Screening factor of cable sheath . .		0.72	0.72	0.73	0.72

For short circuit currents of the order of magnitude shown below, the screening factors of the cable sheath are as follows:

Short-circuit current	A	675	920	1210	1700
Screening factor		0.66	0.61	0.57	0.45

For single-track lines, with a 107 mm² copper contact wire, telecommunication cable about 2.3 m distant from the centre of the track, diameter over the lead 22 mm, lead thickness 2 mm, the following data are quoted:

Load current	A	89	181	272	353	464
Current in the two rails	A	41.2	82.5	127.5	163.5	213
Phase angle		175.5°	175°	172.2°	172°	172°
Current in cable sheath	A	2.05	3.95	5.80	7.25	9.1
Phase angle		136°	141°	137°	139°	141°
Screening factor of cable sheath . .		0.69	0.78	0.66	0.69	0.64

For currents of the order of those of short circuit (1 540 A), the screening factor of the sheath is fixed at 0.43.

Other Administrations have not carried out similar measurements of modulus and phase angle on the screening conductors but have confined themselves (*S.N.C.F.*) to measurements of the modulus as the phenomenon is influenced by many parameters which can be taken into account in the calculation.

It is, incidentally, well known that, as far as the current in the rails is concerned, there is a variation along the track depending on the position of the point concerned in relation to the feed point (substation) and the load point (locomotive). The curve expressing the value of this current which, in its turn, is the resultant of two currents, viz., the traction return current and the current induced in the loop formed by the rails and earth, has its minimum ordinate at the mid-point of this interval and its highest values at both ends.

As the *S.N.C.F.* have shown in their reply, this current also depends on the length of this interval, on the number of lines of rails used for the return current, and on the insulation between rail and soil. It is clear that the parameters to be taken into account are very numerous and that any specific tests will yield results which must be judiciously interpreted, taking into account the influence of the different parameters which play a part under actual test conditions.

However that may be, it can be generally stated that the screening effects may arise from conductors placed in the vicinity of the track and more or less perfectly earthed. The currents induced in these conductors give rise to a marked reduction in the voltage induced in the telecommunication circuits which, over a shorter or longer distance, run parallel to the electrified line. As is well known, this reduction in the value of the voltage induced gives rise to the introduction of the screening factor which expresses the relation between the modulus of the voltage induced when the above-mentioned reduction takes place, and the modulus that would be encountered in the absence of any screening effect.

Actually, this definition of the screening factor, which ignores the phase which the currents induced in the screening conductor have in relation to that of the inductor current, should be supplemented by taking into account the phase relation concerned. It is obvious that the optimum condition for compensation is obtained when this phase difference is close to 180°.

The phenomenon is actually rendered more complicated by the fact that, in practice, the value of the primary current is affected by the presence of one or more screening conductors. It would therefore be necessary to take this reaction into account which is determined by the screening circuit and reflected in a more or less marked increase in the primary current. In most cases, however, this variation in the primary current can be neglected.

As far as the screening effect due to the currents in the rails is concerned, it is well known that, in the interval between the feed point (substation) and the load point (locomotive), these currents result from two components :

— the return current proper, and

— the current induced by the contact wire-earth loop in the rail-earth loop.

The first component undergoes a fairly important attenuation that is the more marked the higher the traction frequency; its value is higher at the feed point and load point (where the load current is evenly divided between the « internal » and « external » branches), but it rapidly decreases practically to zero over a fairly short distance from these two points.

In contrast, the second component, provided that the rails are perfectly earthed over their whole length, would have a constant value between the two points mentioned above.

If the interval between the feed points is fairly long, the current in the rails would be almost exclusively due to the component induced throughout, with the exception of the two terminal zones where the return current component has a significant value and is equally apparent on the inside and on the outside of the interval.

The first component would be the only one to be taken into account if the primary current would circulate in a conductor fairly distant from the rails and connected to the latter by conductors at right angles to the track.

It follows from the foregoing that if the telecommunication circuit extends well beyond the interval between feed point and load point at both ends, the induction effects due to the return current are cancelled out and the effect due to the induced rail current is the only one to be taken into account. In contrast, the currents in the rails outside may give rise to induction effects on circuits which would not be influenced by the current in the overhead line.

A very important factor which must always be taken into account where screening effects are concerned is the extent to which these screening or compensating conductors, be they special conductors or rails or even cable sheaths, are earthed throughout their length.

If these conductors, on the other hand, have a fairly high but finite leakance to earth, it would be necessary to modify the above conclusions considerably, unless the two ends of the conductor are earthed. If the earthing resistance at the two ends of the compensating conductor is fairly small, the induced voltage will be perfectly compensated by the voltage drop in the conductor due to the current circulating in it. The conductor is therefore at the same soil potential throughout, irrespective of the evenly distributed conductor-earth leakance. There is therefore no current passing between conductor and soil, and the current in the conductor remains constant throughout its length.

If, however, the two earthing resistances at the two ends are finite, these conclusions must be modified again. The current in the compensating conductor, instead of remaining constant over the whole length of the interval, will only remain more or less constant in the central part of the interval where the screening effect does not change, irrespective of the conductor-soil leakance. On the other hand, the current at the two ends of the conductor will decrease which will obviously result in a reduction of the screening effect in these two terminal zones.

Whilst in the central section no exchange of current takes place between the conductor and earth, this will happen in the vicinity of the two ends.

If the compensating conductor is extended indefinitely from the two sides of the interval between feed point and load point without any supplementary earth connection, it is possible to substitute for the two indefinitely extended parts two earth connections with an impedance equal to the characteristic impedance of the conductor. The above conclusions remain valid.

One point that must not be overlooked is the need for modifying the above conclusions if, as in the case of the rails, a current directly derived from the contact wire is able to circulate in the compensating conductor. In this case, the screening effect of this current is added to that of the induced current provided that the perturbed current remains completely within the interval between feed point and load point. But, as pointed out above, this favourable additional effect is lost if the circuit is extended on both sides of that interval because the effects of the return currents inside and outside this interval tend to cancel each other out.

It has been deemed useful to quote these observations from the above-mentioned book by Dr. Klewe and from a paper read by Dr. Rosen at the Institution of Railway Signal Engineers, in London, on 12th March, 1958, in order to convey an idea of the great complexity of the problem of the screening effects, and of the difficulty of appraising the real values of the results of practical tests which can be carried out in this matter.

2.211. — As regards the position of the overhead telecommunication and signalling line in relation to the nearest track and the minimum distances permitted, the replies given by the different Administrations are tabulated below.

Distances, m	*R.E.N.F.E.*	*S.N.C.F.*	*Algerian Railways*	*Moroccan Railways*	*F.S.*	*P.K.P.*	*Rhaetian Railway*
Average distance	6	—	4	5	60 (2)	40	50
Minimum distance,	4	3.60 1.95 (1)	—	3	50 (2)	15	20

(1) The S.N.C.F. are only using overhead lines on some of the earlier electrified lines equipped for 1 500 V D.C. The first of these two distances shown in the table applies to the case where the telecommunications and signalling line runs on the same side of the tracks as the masts of the catenary system; the second distance applies to the case where the line is on the opposite side.

(2) The line concerned is equipped for 3.4 kV D.C.

D.B. are always using cabled circuits but there are telecommunication overhead lines belonging to the German postal authorities.

The minimum distance of these conductors from the catenary system is 10 m.

Below that distance, the circuits are always cabled.

The *Catalan Railways* have overhead telecommunication lines plated on L.T. double-petticoat insulators fixed on wooden posts which are, in their turn, mounted on the outside of the supporting structures of the catenary system.

2.212. — *Main characteristics of the overhead lines.*

	Ö.B.B.	*R.E.N.F.E.*	*S.N.C.F.*	*Algerian Railways*	*Moroccan Railw.*	*F.S.*	*P.K.P.*	*Rhaetian Railway*
Height of conductor above ground . . . . . max.	—	10	—	10	8	7.50	5	10
min.	2.50	3	2.50	5	3	5.50	2.50	5
Transverse dimensions of multi connector system max. (m)	—	—	2.60	—	1.35	1.80	—	—
Distance between :								
— pair conductors (m)	0.15	0.20	—	—	—	(1)	0.20	0.25
— quad conductors (m)	—	—	0.42 (square of 0.30 side)	—	0.565 (square of 0.40 side)	—	—	—

(1) The distance between conductors is 20, 30 or 40 cm depending on the circuit characteristics (D.C. telegraphy circuits, audio-frequency circuits, high-frequency circuits).

In the case of the overhead lines of the German postal authorities along the electrified lines of the *D.B.*, the average height of the conductors above ground is 6 m, and the minimum height in mid-span 3 m. The maximum width of the multi-conductor lines is 2.85 m. The minimum spacing of the conductors of a pair is 17 cm and 32 cm for subscriber and local lines, respectively, and 40 cm for long-distance lines. Quads are not used.

On the *S.N.C.F.*, where a telecommunications line crosses a 1 500 V D.C. catenary system, the lowest part of the protective net placed below the telecommunications line must be at least 1 m above the highest part of the catenary system.

As regards the transpositions required to minimize the effects of crosstalk between different telecommunication circuits of the same line and the induction effects of the traction lines, the following particulars can be given :

Ö.B.B. — Length of normal transposition section : 1 000 m.

R.E.N.F.E. — Cross transposition with a very reduced step (200 m).

Catalan Railways. — Transposition every 250 m.

S.N.C.F. — Group transposition by rotation with steps of 250, 500 and 1 000 m.

The *Algerian* and *Moroccan Railways* adhere to the types of fittings and rotation used by the French postal authorities and the *S.N.C.F.* with different steps of rotation for the four quads of the same system.

F.S. — The transpositions by rotation are carried out with a step of 1 000 or 5 000 m. Cross transpositions used for the high-frequency circuits are provided at each mast, or at every second or fourth mast.

The *Rhaetian Railway* uses cross-transpositions with a spacing of 150 m.

P.K.P. are using cross-transpositions only, with section lengths of 16, 6.4 and 3.2 km. Where carrier current circuits are present, the normal section length is 12.8 km.

2.212.5. — Nearly all the Administrations state that they do not use any supplementary transposition with a view to improving the symmetry conditions of the telecommunication circuits relative to the line which gives rise to the induction effects. At most, the frequency of the crossings is increased on sections where a reduced distance between traction line and telecommunication line might give rise to more important disturbing effects.

2.212.6. — Earth return circuits are never used for telecommunication lines running parallel to electrified railways.

2.213.1-2-3. — The replies received do not contribute much to the clarification of these questions.

Among the replies, that of the *P.K.P.* does, however, contain some interesting details based on tests.

The measured values of the sensitivity coefficients range generally from 0.006 to 0.089. Higher values are encountered on train control circuits because of the very great number of connections to lineside installations which make it difficult to ensure balanced conditions.

On the overhead lines of the German postal authorities along the electrified lines of the *D.B.*, the sensitivity coefficient is reckoned to be 0.025.

Tests are being carried out.

Though these values are undoubtedly subject to seasonal variations, no systematic observation has been carried out.

It may be of interest to present some commentary on the data given above.

As regards the distance between the telecommunication line and the nearest catenary, it is clear that the risk of close approach or even direct contact between the conductors of these lines as a result of mechanical disturbances, violent gusts of wind or other accidents would call for distances of the same order of magnitude as the greatest height of the conductors of these lines above ground.

Moreover, it would be necessary to take into account, in this connection, the relative position of the two lines not only in the horizontal projection but also in the vertical projection, and the cases to be considered would be very numerous and possibly of fairly little importance.

On the other hand, it is obvious that, with well designed and constructed installations offering an adequate safety margin from a mechanical point of view, such contingencies can be regarded as extremely improbable.

For that reason, we shall here confine ourselves to a consideration of the induction effects alone.

As far as the protection against magnetic induction effects is concerned, it is well known that the mutual inductance M on which the phenomenon depends will only decrease fairly slowly with the distance.

It follows that, if this distance does not become fairly great, the improvements that can be expected from shifting the telecommunication line further away are not very great.

A more important part is played by the transpositions of the conductors which, in the ideal case, can ensure such symmetry conditions that the induction effects can be regarded as negligible provided that there are no other disturbing effects which would, in practice, be able to affect the anticipated conditions considerably.

As the circuits of the telecommunication line are often numerous, there is, in addition to the problem of the induction effects of the traction line, the problem of the crosstalk effects between telecommunication circuits.

In this case, it is necessary to resort to a transposition scheme. Such a scheme exists with the different postal and railway authorities and is based on transposition lengths so arranged that adjacent sections have a length ratio of 2 : 1, e.g. 8, 4, 2, 1. It would be permissible to use the same

length for two different circuits provided that the transposition points are suitably staggered so that the transpositions of one circuit are arranged at the mid-point of the transposition length of the other circuit.

If the minimum length is not to be too short, a « basic length » must be adopted which is represented by the longest transposition distance, i.e., in the case here considered, 8 times the minimum distance, which is therefore fairly long.

It should be noted that, if the crosstalk effects are perfectly compensated (at least in principle) over the basic length, the compensation of the induction effects due to the traction line is only obtained over twice that length.

In the case of electrified railways where the interval between the feed points (sub-station) and the load points (locomotive) is variable, the value of the greatest transposition length plays an important part, in contrast to power supply lines where the transposition length of a telecommunication line running parallel to it over a long distance is not an essential factor.

When a train moves away from the sub-station, the effect is increasing until the transposition length is reached, because the non-compensated length of parallelism increases. Beyond the transposition length, an increasing compensation takes place so that the induction effects are reduced until the above interval amounts to twice the mentioned inversion distance.

The inductive effects will therefore fluctuate as a function of that distance.

It would therefore be advantageous to make the minimum transposition distance for the most transposed circuit as small as possible so that a certain value of the non-compensated distance and induction effects of the non-transposed circuit is not exceeded. But there are practical limitations in this respect, and it is only with carrier current circuits that very short transposition distances are adopted.

If the transpositions of the line can lead to favourable conditions as regards the balance of the overhead circuit, it is obviously necessary to consider the balance of the whole system with its terminal installations.

Even if the transpositions are perfectly regular, a certain unbalance is always possible, and may undergo important variations due to irregularities caused by atmospheric factors or other causes, which is unavoidable on overhead lines.

2.22. Cables.

2.221. — Arrangement of the cables used in telecommunications and signalling installations.

Overhead cables arl used by *R.E.N.F.E.* The *F.S.* also use overhead cables of the self-supporting type, but only on lines with lighter traffic. *P.K.P.* use overhead lines exceptionally for local communications.

Underground cables are of the buried type with the following Administrations:

D.B. (for A.C. electrified lines); *S.N.C.B.; Lower Congo-Katanga Railway; S.N.C.F.; R.A.T.P.; Algerian Railways; F.S.; Rhaetian Railway; N.S.; P.K.P.*

Laying in troughs is resorted to by *D.B.* along D.C. electrified lines, on the open line as well as in the stations, as a corrosion protection measure, and by the *Moroccan Railways* who, incidentally, use cables over short distances only, and only for lack of space.

Many Administrations, though using buried cables along the open line, use cable troughs in the stations, especially for signalling cables, or if the cables have no lead sheath (e.g. plastics or rubber). Among these Administrations are *Ö.B.B., S.N.C.B., S.N.C.F., Algerian Railways, F.S.*

2.222. — In the case of overhead cables, *R.E.N.F.E.* adopt a minimum distance of 3 m between the cable and the contact wire.

Where the *F.S.* resort to overhead cables of the self-supporting type, they use the supporting structure of the catenary system for this purpose, and the minimum distance from the contact wire is 3 m.

2.223. — In the case of buried cables, representing the type most frequently encountered, the position of the cable in relation to the nearest track varies considerably with the different Administrations.

The Table below provides some data on this subject :

	Ö.B.B.	*D.B.*	*S.N.C.B.*	*Lower-Congo Railways*	*S.N.C.F.*	*Algerian Railways*	*F.S.*	*N.S.*	*P.K.P.*	*C.F.F.*
Position of the cable in relation to the centre of the nearest track (m)	4.50	12 (average)	5	1.70	at railway boundary	3	3 (*) (min. 2)	3 (min.)	at railway boundary (min. 2)	2 (*) (min.)
Depth of buried cables (m)	—	0.80	0.60	0.60	0.80	0.80	0.40(*) min.	0.60	0.80	0.40 (*)

(*) On the F.S. and C.F.F., the distances vary to a fairly considerable degree according to whether the line is straight or curved. The distance may also vary according to whether, on single track lines, the cable runs on the same side or on the opposite side of the supporting structures of the catenary system.

Note : The depths of buried cables are in relation to ground level.

2.224.1. — Cable structure used.

A. — *On D.C. electrified lines.*

S.N.C.B. — Dry paper type insulation. The cable core is insulated against the lead sheath by paper tape wound helically. Lead sheath with special additives to increase its resistance to intercrystalline corrosion. Steel tape armouring without particular specifications. Sheath and armouring are protected by two tapes of bituminized textile fabric which, in their turn, are wrapped in jute yarn saturated with natural bitumen or mineral oil.

Long distance cables with insulation of plastics are coming into use :

conductors insulated with solid polythene, screen of electrolytic copper, relatively thick sheath of polyvinyl chloride. Armouring, if any, as for conventional cables but merely for the purpose of affording protection against rodents, and not that of improving the screening factor.

R.E.N.F.E. — Cable with paper insulated cores; lead sheath; steel tape armouring.

Algerian Railways. — Polythene insulated core; polyvinyl chloride sheath; armouring of aluminium tape (used experimentally).

Moroccan Railways. — Telephone cable of « interurban » type; conductors insul-

ated with dry manilla paper; lead sheath externally protected by polyvinyl chloride sheath; no armouring. Apart from their functional characteristics, these cables have been chosen for their particularly good resistance to electrolytic corrosion, an important factor in view of the general nature of the soil.

N.S. — 1. *Telecommunication cables :* cores insulated with paper and dry air; sheath of lead or aluminium; armouring with two steel tapes for lead sheath; otherwise no armouring.

Use is also made of cables with polythene insulated cores; polyvinyl chloride sheath with copper conductors and copper tape to improve the screening factors; no armouring.

2. *Signalling cables :* cores insulated with impregnated paper; lead sheath; armouring consisting of one layer of steel wire and one steel tape.

Use is also made of cables with P.V.C. insulated cores; polyvinyl chloride sheath (if the cables also contain telephone circuits, one also uses copper conductors, and possibly, a copper tape as with the cables described above); no armouring.

Protection against electrolytic corrosion is ensured : for telephone cables with dry paper insulation, by the layers of bitumen impregnated paper and bituminized jute. For telephone cables with aluminium sheath, by an external sheath of polyvinyl and bitumen; for cables of plastics, by the P.V.C. sheath.

Protection for signalling cables is ensured in the same way.

P.K.P. — Cores insulated with paper and dry air; lead sheath; steel tape or steel wire armouring without special specifications as regards permeability.

Protection against electrolytic corrosion, mostly obtained by means of drainage, is sometimes entrusted to insulating joints.

There are also lead sheath cables with an outer layer of P.V.C., as well as cables with neoprene sheath.

B. — *On A.C. electrified lines.*

Ö.B.B. — Cables with dry paper insulated cores; lead sheath; armouring; corrosion protection.

D.B. — Cable with paper insulated core; sheath consisting of *a*) lead; *b*) aluminium; *c*) corrugated steel sheeting; sheaths of types *b*) and *c*) are specially corrosion protected (outer sheath of P.V.C.); armouring by two layers of steel tape.

The armouring of the cables with P.V.C. sheath consists of high permeability steel; the armouring of the cables with aluminium or corrugated steel sheath with auxiliary conductors to reduce the longitudinal resistance consists of ordinary steel.

Lower-Congo-Katanga Railways. — Cables with paper insulated cores where the insulation between the conductors and the lead is reinforced (6 layers of 0.13 paper between the conductor assembly and the lead); thicker lead sheath than with ordinary telephone cables (2.2 mm thickness instead of 1.5 mm for a 20-stranded cable); armouring of ordinary steel tape but greater thickness (2×0.7 mm instead of 2×0.5 mm).

S.N.C.F. and *F.S.* are using the same types of cables, with certain exceptions and limitations, for D.C. and A.C. lines, respectively. The following cables are used :

S.N.C.F. :

a) *telecommunication cables :* dry paper insulation; lead sheath; mild steel armouring without special feature;

b) *signalling cables :*

1) cables exceeding 100 m in length :
— impregnated paper insulated cores; lead sheath; mild steel armouring without special feature;

2) polythene insulated cables, armoured as above, without lead (preferably used on D.C. lines, with certain qualifications as regards the length of circuits on A.C. electrified lines);

3) signalling cables less than 100 m in length :

— rubber insulated cable with chloroprene sheath;

c) *mixed telecommunication and signalling cables :* polythene insulated cores with P.V.C. sheath; armouring consisting of one steel tape and one aluminium tape.

In the case of lead-less and armoured cables a supplementary protection of the armouring is used on D.C. electrified lines which may consist of coated glass fibre tape or a P.V.C. sheath. On lines electrified with single-phase current, a coated glass fibre tape is used for the telecommunication cables only.

F.S. — Core insulated with paper and dry air; lead sheath; *no armouring*; external sheath of rubber or plastics as a protection against electrolytic corrosion.

Signalling cables : rubber insulated cores; lead sheath; external protection of rubber or plastics.

Increasing use is also being made of rubber insulated cables with thermoplastic sheath.

C.F.F. — Cores insulated with paper and dry air; lead sheath, ordinary iron armouring, two tapes of 0.8 × 30 mm; protection of the sheath by the bituminized jute only.

Rhaetian Railway. — Cores insulated with dry paper; lead sheath with 2 % tin; iron tape armouring.

2.224.2. — Among the Administrations using cables without metal cover, those who resort to armouring with ribbons or tapes of steel adopt this measure not for the improvement of the screening factor but rather as a supplementary protection from a mechanical point of view and against rodents.

The *Ö.B.B.* have recently used « Alplast » cables with aluminium sheath on which a layer of P.V.C. is placed in order to protect it against corrosion. The screening factor is improved by means of iron conductors embedded in the sheath.

In contrast, copper screening is used for cables of the *S.N.C.B., R.A.T.P.* and *N.S.*

The *S.N.C.F.* use an aluminium screen in signalling cables of great length. Mixed signalling and telecommunication cables are provided with an armouring consisting of a steel tape and an aluminium tape.

The *F.S.* use iron tape screenings for their overhead cables.

2.224.3. — The test voltages and breakdown voltages are specified as follows :

Ö.B.B. — The breakdown voltages are 3 200 to 3 800 V for a frequency of 16 2/3 c/s, and 3 500 to 4 000 V for 50 c/s. A test voltage of 1 800 V is applied for the duration of 2 min between conductors and sheath, and 500 V between conductors.

D.B. :

Test voltage between conductors and metal sheath : 2 kV;

Corresponding breakdown voltage : 3.5 kV.

For cables of plastics :

Test voltage between conductors : 2 kV;

Corresponding breakdown voltage : 22-26 kV;

Breakdown voltage between conductors and armouring : 35 kV.

S.N.C.B. :

Test voltage between conductors and metal sheath : 1.8 kV;

Corresponding breakdown voltage : 4.5 kV.

Lower-Congo Railways :

Test voltage : 0.5 kV between pairs of the same quad;

3.0 kV between quads and in other conductors to mass.

The respective breakdown voltages are 2.5, 7.8 and 6.6 kV.

R.E.N.F.E. — Test voltage : 0.7 kV.

S.N.C.F. — For telecommunication cables :

Test voltage between conductors : 0.75 kV;

Test voltage between conductors and metal screen : 2 kV;

For signalling cables : 2.5 kV;

For mixed signalling and telecommunication cables :

3 kV between signalling conductors;

4.5 kV between telecommunication conductors;

8 kV between conductors and armouring.

Where a sheath of plastics is used, this sheath must withstand a breakdown voltage of 2 to 3 kV depending on the cable diameter.

R.A.T.P. — Between tape and core : 1.5 kV.

Moroccan Railways. — Breakdown voltage exceeding : 2.5 kV.

F.S. — Test voltage between conductors and lead sheath : 2 kV.

N.S. — Test voltage between conductors and metal sheath or screen :

a) for telephone cables : 1.8 kV for the duration of 5 sec;

b) for signalling cables : 2 kV for the duration of 15 min.

P.K.P. — Test voltage : 2 kV for the duration of 2 min.

C.F.F. — Test voltage : 2 kV for the duration of 10 min.

The tests referred to above are acceptance tests which are carried out at the manufacturers' works.

2.224.5.

Ö.B.B. — The cable joints are carefully short circuited; the same applies to the heads of shunting and end cables.

D.B. — Isolating cable joints are not shunted by capacitances or filters.

S.N.C.B. — The lead sheaths of the main cables are sometimes cut at certain railway junctions, main stations, etc., where isolating joints are used so as to obtain the protection potentials against electrolytic corrósion.

Where the cable contains circuits used for transmission by carrier currents, use is made of capacitances of 1 μF to shunt the discontinuity of the sheath. This precaution is intended to ensure the continuity of the sheath to high frequencies (120 kc/s).

Lower-Congo Railways. — The sheath is partitioned every 15 km or so but the sheaths of the two ends of cables are electrically connected by a galvanised wire of 20/10 mm. At each joint, the tapes are soldered to the lead at the two ends.

R.E.N.F.E. — The lead sheath is partitioned in order to prevent the circulation of the D.C. traction currents; no capacitances are used to shunt the gaps.

S.N.C.F. — Along the lines equipped for single-phase 50 c/s, 25 kV, the continuity of sheath and armouring is ensured over the whole length of the cable between two sectioning points. The heads of the branch and end cables are electrically connected to the sheathing of the main cable and to the supporting frame of the cable heads.

The continuity of the sheath (lead plus tape) is ensured as far as D.C. is concerned, but the cable heads are insulated against the supporting frames or the cable sheath by insulating sleeves in order to obtain cathodic protection.

Algerian Railways. — No isolating joints.

Moroccan Railways. — The lead sheath is interrupted at the distributors. It is insulated against earth, and the continuity between sections is not ensured. Neither capacitances nor filters are used.

F.S. — With buried cables, the lead sheath is interrupted at every loading coil pot (at intervals of approx. 1 830 m), but no capacitances or filters are used in order to maintain the screening effect of the sheath.

N.S. — The continuity of the sheath is never interrupted in order to obtain the full screening effect.

C.F.F. — The sheath is interrupted at the terminal boxes, at the lineside distributors, but these gaps are carefully bridged by a copper wire of large cross section.

Rhaetian Railway and P.K.P. — The continuity of the sheath is not interrupted.

2.224.6. — With the *Ö.B.B.*, the sheath is earthed.

D.B., S.N.C.F., N.S. — It is thought that, with cables not provided with special corrosion protection, special earthing measures are not required. This earthing is ensured by the sheath itself.

Moreover, on lines electrified at 25 kV, 50 c/s, the *S.N.C.F.* connects electrically at the sectioning points the armourings of the cables between them and to the masse of the chassis-supports of the heads of the cables. The whole is connected to the earth.

S.N.C.B., R.E.N.F.E., R.A.T.P., Algerian Railways, C.F.F., Rhaetian Railway, P.K.P. — The sheath is not earthed.

Lower-Congo Railways. — The cable sheath is earthed at certain stations, every 100 km or so.

F.S. — The lead sheath of buried cables which is protected by an external insulating sheath is never earthed. With overhead cables, however, the armouring is earthed at all stations.

2.224.7. — Screening factors.

D.B. — The screening factors K measured in modern cables for a frequency of 16 2/3 c/s are given in the attached diagrams (figs. 4*a* and 4*b*) for armoured cables with lead and aluminium sheath, respectively, as a function of the induced longitudinal e.m.f. per unit of length.

Ö.B.B. — The screening factors K for cables of different types used on electrified lines are given on the diagrams (figs. 4*c* and 4*d*).

S.N.C.F. — The metal sheaths (lead and tape) which surround the conductors gives rise to a screening factor depending on the inducing field, i.e. on the current in the catenary. For fairly low current values (some hundred of Amps on lines electrified for 25 kV, 50 c/s), the reduction factor is of the order of 0.4 to 0.5 at 50 c/s.

Under short-circuit conditions, the value of the reduction factor may attain 0.2 for 2 000 A. A good mean value is 0.3 for heavy currents.

F.S. — In view of the fact that the lead sheath of buried cables is interrupted at short intervals and is not earthed, the screening possibilities are not utilized. In overhead cables, the screening factor of the carrier and of the metal armouring has been estimated at approx. 0.5.

N.S. — The screening factors of cables with P.V.C. sheath and with copper wire and copper tape screening are as follows:

0.96 at 50 c/s;
0.86 at 100 c/s;
0.75 at 150 c/s;
0.65 at 200 c/s;
0.56 at 250 c/s;
0.50 at 300 c/s.

C.F.F. — With telecommunication cables placed about 2.3 m from the centre line of the track, having a diameter over the lead of 45 mm, and a lead thickness of

a)

b)

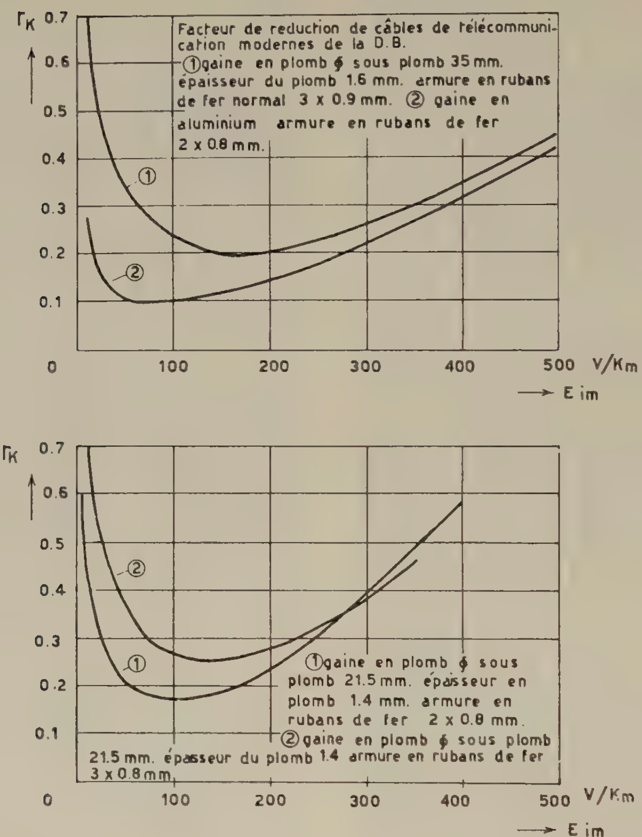


Fig. 4 *a* et *b*.

Explanation of French terms :

a) Facteur de réduction de câbles de télécommunication modernes de la D.B. = screening factor of modern telecommunication cables of the D.B. — (1) Gaine en plomb : diamètre sous plomb, 35 mm; épaisseur du plomb, 1.6 mm; armure en rubans de fer normal, 3 × 0.9 mm = lead sheath : diameter under lead, 35 mm; lead thickness, 1.6 mm; armouring of normal iron tape, 3 × 0.9 mm. — (2) Gaine en aluminium : armure en rubans de fer, 2 × 0.8 mm = aluminium sheath : armouring of iron tape, 2 × 0.8 mm. — *b*) (1) Gaine en plomb : diamètre sous plomb, 21.5 mm; épaisseur en plomb, 1.4 mm; armure en rubans de fer, 2 × 0.8 mm = *b*) (1) lead sheath : diameter under lead, 21.5 mm; lead thickness, 1.4 mm; armouring of iron tape, 2 × 0.8 mm. — (2) Gaine en plomb : diamètre sous plomb, 21.5 mm; épaisseur du plomb, 1.4 mm; armure en rubans de fer, 3 × 0.8 mm = lead sheath : diameter under lead, 21.5 mm; lead thickness, 1.4 mm; armouring of iron tape, 3 × 0.8 mm.

3 mm, the creening factors of the sheath on double track lines, with currents in the catenary system of :

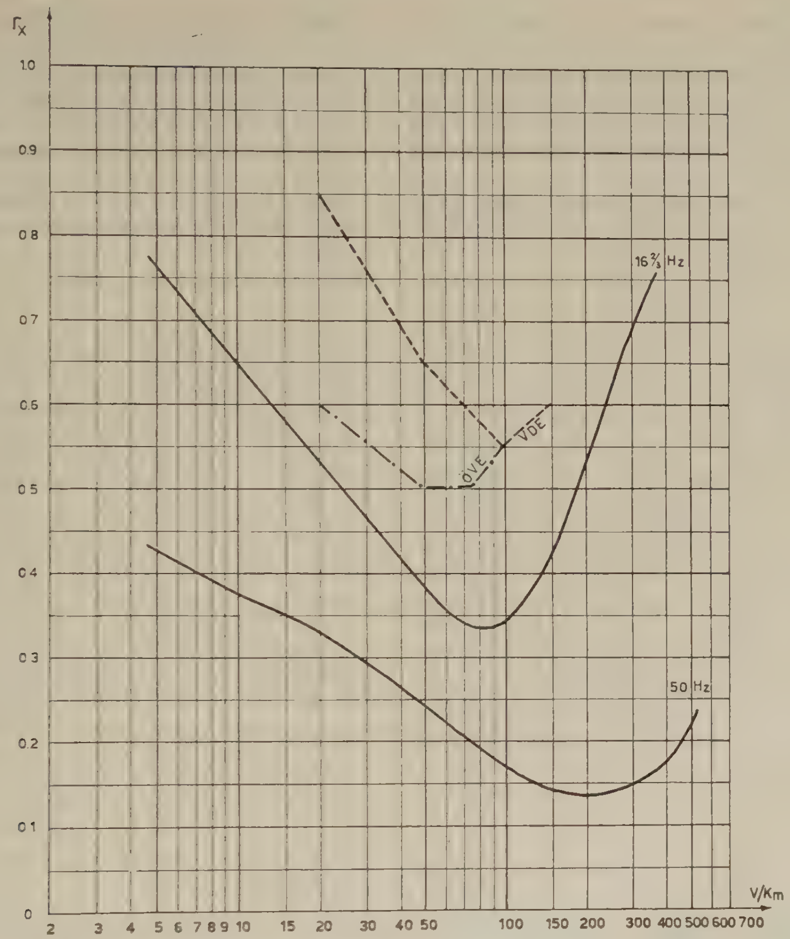
88 176 264 408 A

are as follows :

0.72 0.72 0.73 0.72

With short circuit currents of :

675 920 1 210 1 700 A



Câble de télécommunication ÖBB
Diamètre sous plomb 35.0 mm.
Épaisseur du plomb 2.2 mm
Armure 2 x 0.8 mm. bandes d'acier

Fig. 4*c*.

Explanation of French terms :

Câble de télécommunication Ö.B.B. = Ö.B.B. telecommunication cable. — Diamètre sous plomb : 35.0 mm = diameter under lead : 35.0 mm. — Epaisseur du plomb : 2.2 mm = lead thickness : 2.2 mm. — Armure : 2 × 0.8 mm bandes d'acier = armouring of steel tapes : 2 × 0.8 mm.

the screening factors are :
0.66 0.61 0.57 0.45

On single track lines and with telecommunication cables having a diameter over lead of 22 mm and a lead thickness of 2 mm, in the position described above, and for load currents of :

89 181 272 353 464 A

the measured screening factors of the sheath are :

0.69 0.68 0.66 0.69 0.64

With a short circuit current of 1 540 A, the screening factor of the sheath is 0.43.

Rhaetian Railway quotes a screening factor value of 0.8.

The replies of the other Administrations do not provide further information on this subject.

utilisation of the compensating effect of the currents circulating in the rails.

Buried cables also have other advantages over overhead cables, also from an operating point of view, as they are better protected against any damage due to outside effects.

Furthermore, the use of buried cables has the following advantages compared with overhead lines :

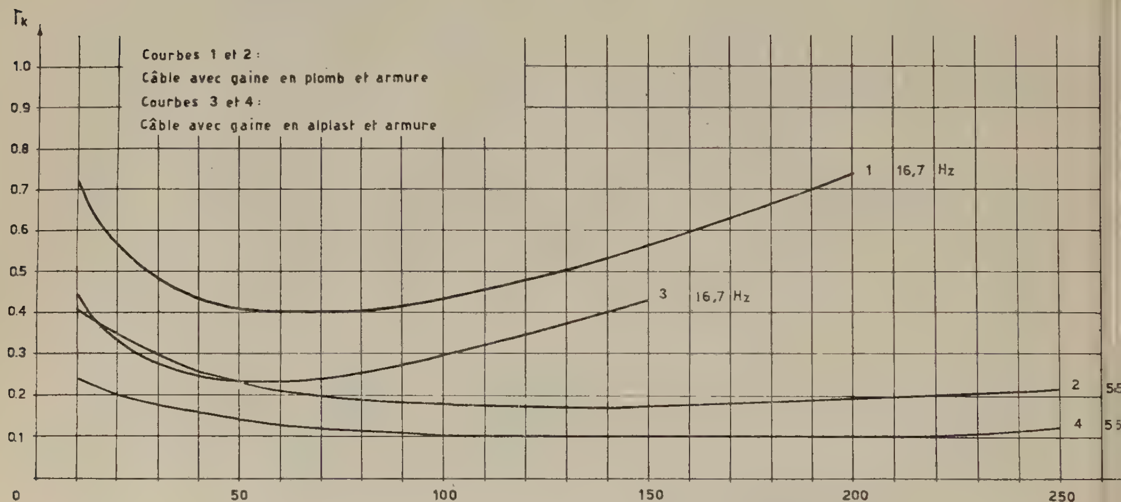


Fig. 4*d*.

Explanation of French terms :

Courbes 1 et 2 : câble avec gaine en plomb et armure = curves 1 and 2 : cable with lead sheath and armouring. — Courbes 3 et 4 : câble avec gaine en alplast et armure = curves 3 and 4 : cable with « alplast » sheath and armouring.

Comments on the subject of cables and cable structure.

Cables have well-known advantages which justify the preference given to them by many Administrations over overhead lines, and which largely make up for their higher price.

As far as cable laying is concerned, it is certain that buried cables have many advantages over overhead lines because of their greater distance from the catenary, and because they permit a more effective

1) there is no risk of direct contact between telecommunication line and the catenary or any other traction conductor (feeders, etc.) along the track;
2) all effects of electric influence are practically eliminated;
3) a decisive decrease of any magnetic induction effect is obtained;
4) the telecommunication circuit characteristics are constant and do not show the variation inevitably encountered with overhead circuits.

The cables are very often simply buried.

Expensive laying in troughs can only be justified in certain special cases as, for instance, in the stations, and particularly for signalling cables. In this case, it is often necessary to lay many cables side by side in the same duct where the use of troughs enables the cables to be laid in conditions more favourable for future inspection, and results in better conditions for the mechanical protection of all these cables.

As regards the position in relation to the track of buried cables along the open line, it may be pointed out that, if the distance from the rails is thereby reduced, the compensating effect due to the currents in the rails is enhanced, which may well balance the unfavourable effect due to the increase in the magnetic induction effect produced by the current in the catenary system. This consideration may justify the fairly short distances between the cable and the nearest rail, quoted above.

Dr. KLEWE confirms in his book that the maximum induction effect is encountered at a distance of 3 to 5 m from the nearest rail.

One factor of the greatest importance, which well explains the superiority of the choice of cables, and particularly of buried cables, over that of overhead circuits, is the screening effect due to the metal sheath of the cables. This effect is well known to be very effective because of the very short distance separating the sheath from the induced circuits.

The theoretical study of the question shows that any reduction in the ohmic resistance of the sheath which can, other factors being equal, be obtained by increasing the thickness of the sheath and by choosing, for the sheath, a metal of lower resistivity, results in a considerable improvement (i.e. reduction) of the value of the screening factor. It may be argued that the increase in the thickness of the sheath represents a fairly costly solution which also has certain practical drawbacks. There are therefore certain limits which one prefers not to exceed. The use of aluminium instead of lead has certain advantages because aluminium has less resistivity than lead. Admittedly, aluminium calls for more carefully designed special protection against corrosive actions on the surface than lead. For this purpose, however, it is possible to use an external protective sheath (e.g. one made of plastics) and earthing devices of fairly low resistance at determined points.

Later on, we shall mention the difficulties due to the risks of electrolytic corrosion owing to which it becomes impracticable to make full use of the screening possibilities given by the sheath. This applies to D.C. electrified lines. But even in this case, special solutions are still possible.

Another factor which has a bearing on the assessment of the screening effect of the sheath on the conductors inside is the inductance of the sheath.

This is explained by the consideration that the voltage induced in the conductor is equal to the ohmic drop due to the currents circulating in the sheath.

This justifies the tendency mentioned above of reducing the ohmic resistance of the sheath and, at the same time, reducing the value of the currents in the sheath, which can be achieved by increasing the inductance of the sheath.

It must not be overlooked that, according to a more profound study, the mentioned e.m.f. induced on the conductors is proportional to the product of the current density on the internal surface of the sheath and the ohmic resistance of the sheath itself. This gives rise to a fairly considerable eventual reduction in the induced e.m.f. at high frequencies because, owing to the skin effect, the greatest part of the current circulates on the outer part of the sheath.

The increased inductance can be obtained by armouring the outside of the metal sheath with magnetic materials.

It is by no means necessary to use special materials of very high magnetic permeability, and the improvement in the screening effect thereby obtainable would

not justify the much higher price of the cable.

It must be added that, in many cases, the permeability of these materials does not survive the mechanical treatments to which they are subjected when the armouring is applied to the cable.

It is sufficient for the armouring to provide a cylinder of magnetic material which has practically no air gaps, as for instance with armourings of steel wire. Armourings of ordinary steel tape provide the most convenient solution.

The screening factor is improved (i.e. reduced) by higher frequencies.

As the permeability depends on the magnetic induction which, in its turn, depends on the current in the sheath, i.e. on the induced e.m.f., it is possible to observe a reduction (improvement) of the value of the screening factor as the mentioned e.m.f. increases, up to the moment when saturation is reached and the screening factor will again increase.

It is therefore necessary to ensure that this saturation effect can only be produced under conditions which are outside those encountered under short circuit conditions, or are at least of the same order of magnitude.

It may still be mentioned that, if the earth connection of the cable sheath is in the form of a finite resistance, the phenomenon is more complicated and the current in the sheath depends on the length of cable concerned (length of parallelism) while the values of the screening factor are reduced as the length of parallelism increases.

These considerations may be concluded with the observation, already inherent in what has been stated above, that more favourable (i.e. smaller) reduction factors can be obtained more easily by a higher frequency (e.g. 50 c/s) than by a lower frequency (e.g. 16 2/3 c/s).

2.23. Special protection devices.

2.231.1. — The sectionalisation of the circuits by means of isolating transformers with a ratio of 1 : 1, designed to limit the value of the induced longitudinal voltage, is resorted to by the *S.N.C.F.* on lines electrified for 25 kV, 50 c/s. The sectioning points are determined from a calculation of the induction.

Translators are also used by the *Ö.B.B.* on the different circuits, except for local telephone circuits and D.C. dialling. Additional sectioning is resorted to in the case of induction by three-phase lines.

Most of the Administrations do not systematically resort to such intermediate sectionalisation, obtained in this way.

Translators are obviously used at terminal points as well as on branch lines in order to obtain the highest possible degree of symmetry.

2.231.2. — On the *S.N.C.F.*, the distance between successive sectioning points is of the order of 15 km; the maximum distance is 20 km.

Where a systematic sectionalisation of the conductors by means of translators has not been resorted to, the distance between two consecutive sectioning points to be taken into account in this connection, can fairly often be identified with the mean distance between two successive repeaters where translators are often used.

The *Ö.B.B.* aim at limiting the value of the longitudinal voltage induced in the event of a short circuit on the traction line to, at most, 60 % of the test voltage of the cable (approx. 1 100 V).

2.231.3. — The *S.N.C.F.* have adopted the principle that the crest value of the longitudinal e.m.f. induced between two successive translators must not exceed 60 % of the lowest dielectric strength of the installation.

It is partly on the strength of this consideration, and partly on the short-circuit value that the spacing of the sectioning points is determined.

The test voltage between conductors is 700 V.

The breakdown voltage between conductors and armouring is 2 000 V. The maximum voltage is therefore 0.60 × 700 = 420 V.

Among the Administrations which do not resort to systematic sectioning of this kind, the following values are stated for the voltages induced on the signalling and telecommunication installations.

D.B. — The maximum voltages experienced under normal working conditions are 125 V for overhead signalling circuits and 250 V for cabled telecommunication circuits. These values rise to 300 V in the event of a short-circuit on the catenary in the former case, and to approx. 60 % of the test voltage in the case of cabled circuits.

For the calculation of the induced voltage in the event of a short-circuit on the catenary system, a value of 70 % of the short-circuit current is used, which can be ascertained under the most unfavourable conditions.

S.N.C.B. — The induced longitudinal voltage may, in the event of a violent short-circuit on the catenary, attain a value of 300 to 550 V, i.e. about one-fifth of the test voltage and one-tenth of the breakdown voltage.

Lower-Congo-Katanga Railways. — The maximum calculated values of the induced voltage are 118 V for working current and 1 790 V for a direct short-circuit at the end of a section. A safety factor of 1/0.6 has been adopted for the determination of the test voltages of the cables.

The maximum voltage measured with normal traction loads has been 350 V.

The Moroccan Railways do not attach great importance to this question in view of the short length of the cables used.

In any case, the induced voltage would always be smaller, even in the event of a direct short-circuit, than half the test voltage of the cables (12 kV).

F.S. — With the *F.S.*, too, the induced longitudinal voltage encountered is much below 0.6 times the value of the test voltage of the cables.

C.F.F. — A maximum induced voltage of 1 800 V is reckoned with, corresponding to 80 % of the test voltage.

2.231.4. — The maximum voltages between conductors have been determined on the strength of the following assumptions :

Ö.B.B., D.B., S.N.C.F. — Conductors earthed at two different points.

S.N.C.B. — The value of this voltage is fairly small under normal operating conditions. The measured ratio of transverse and longitudinal voltage is of the order of 1 : 1 000.

The replies received from the other Administrations do not contain further information beyond that given above.

2.232. — As regards the question of modification of the test voltage values according to whether or not translators are used, *D.B., S.N.C.F.* and *F.S.* state that they do not reckon with any difference in the two cases as far as the test voltages are concerned.

On the *Ö.B.B.* who, as already mentioned, normally make use of translators, the aim is not to exceed induced voltages of a value which might be dangerous to the personnel (maximum 300 V during 150 millisec).

2.233.1. — This question obviously applies exclusively to the case where systematic sectionalisation by intermediate translators is used.

The *S.N.C.F.* are permanently watching the insulation of the telecommunication cables by means of a D.C. current supply (220 V) between earth and the super-phantom of each of the quads of the cable.

At the gaps, the super-phantoms are

made continuously by low-pass filters (highly insulated resistances and capacitances) which block the induced alternating voltages but let the D.C. control current pass.

2.233.2. — The reply given by the *S.N.C.F.* is as follows :

The questions discussed above exclusively concern long cables, viz., telecommunication cables.

With long signalling cables, the insulation control is not permanent and is carried out from time to time, section by section, with an adequate measuring instrument.

2.233.3. — The *S.N.C.F.* declare that the solution by sectionalisation obtained by translators has always been found acceptable.

2.234.1, 2.234.2, 2.234.3, 2.234.4. — As regards the protection devices referred to in these questions, the *Ö.B.B., D.B.* and *F.S.* state that no protection devices against overvoltages or overcurrents are used in the cable circuits.

The *Ö.B.B.* normally use for their overhead lines lightning arresters with a flashover voltage of 350 V.

The overhead lines of the *D.B.* do not call for any special protection against the dangers liable to arise from the electrified lines along which they are installed.

S.N.C.B. — No protection is used for cabled circuits.

At the points where the cables are connected with overhead lines, conventional devices are used, with the following items, arranged consecutively :

— a spark gap;

— a 3 A fuse;

— a vacuum typ elightning arrester;

— a fuse of 0.3 A.

R.E.N.F.E. — Fuses are being used.

S.N.C.F. — No protection is used on circuits terminated by translators.

In the absence of the latter, the circuits are protected by special 5 A fuses for electrified lines, with or without simple lightning arresters with striking voltages from 800 to 1 100 V.

Protection of the overhead lines is achieved in the same way, but the special fuses for electrified lines are supplemented by lightning arresters.

Moroccan Railways. — As far as overhead lines are concerned, the type of protection used does not differ greatly from that used by the *S.N.C.F.*, described above.

F.S. — Fuses of 6 A and lightning arresters with a flahsover voltage of 350 V are used.

C.F.F. — There is no overcurrent protection on circuits equipped with translators. In other cases, 5 A fuses are used.

P.K.P. — No protection is normally provided for cabled circuits. With overhead lines, protection devices are used which consist of a metallic lightning arrester of the point or comb type, a fuse of 2 to 7 A and a gas filled glass valve type lightning arrester with a striking voltage of 400 V.

No special reasons are put forward for the values adopted for the breakdown currents and voltages in those cases where protective devices are used.

2.234.5. — Protection devices against acoustic shocks are used by the following Administrations :

Ö.B.B., D.B., S.N.C.B., S.N.C.F., F.S. (for train control circuits on overhead lines : *C.F.F.*).

The devices are of the conventional type with rectifier cells in bridge connection or parallel-opposition connection.

2.235. — Most of the Administrations do not use any special protection devices other than those described above.

N.S. are mentioning two special devices. The first consists of a two-winding longitudinal choke transformer ratio 1 : 1, the two windings being series-connected to the conductors of the line (cf. diagram, fig. 5). In the case of rather long extensions connected to a switchboard, these chokes serve to separate the external circuit from the internal circuit of the switchboard which is not always perfectly balanced.

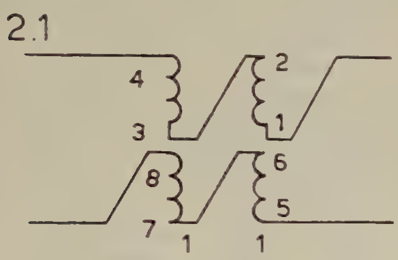


Fig. 5.

The other device consists of multiple filters which are designed to eliminate, in telephone circuits and in signalling cables, the harmonics of 300, 600, 900, 1 300 and 1 500 c/s due to the traction circuit.

It is well known that, in the case of very long circuits, even in cables, the value of the induced longitudinal e.m.f. can, even if the screening factor of the sheath is taken into account, assume very high values which would call for the use of types of cable which are able to withstand high voltages so that fairly high test voltages and breakdown voltages would have to be specified. It would thus become necessary to use, in these cases, very expensive special cables.

In contrast, the solution of systematic sectionalisation obtained by means of 1 : 1 transformer inserted in the circuits at judiciously chosen intervals makes it possible to limit the value of the voltage which the cable must be able to withstand.

As the value of the longitudinal e.m.f. per unit of cable length is known, it is possible to use, even in this case, the type of cable standardized for general use, provided that the distance between successive sectioning points has been fixed so as not to exceed an appropriate fraction (determined with a view to an adequate safety margin) of the test voltage of the cable. Obviously the safety margin in relation to the breakdown voltage becomes even greater.

As regards the voltage between a conductor and the sheath, the most unfavourable condition is encountered when there is contact with the sheath at one of the ends of the section considered. The most unfavourable conditions for a voltage between two adjacent conductors are encountered when each of the conductors has contact at one of the two ends of the section.

The solution of systematic sectionalisation at intervals of a length not exceeding the maximum value referred to above thus gives rise to considerable savings and is very satisfactory in practice.

This sectionalisation of the circuits into sections of a length which, on the 25 kV, 50 c/s lines of the *S.N.C.F.*, has been fixed at between 15 and 20 km on the strength of the above considerations, naturally gives rise to certain problems which are, however, fairly easy to solve.

One of these problems is that of the permanent control of the insulation on the different sections.

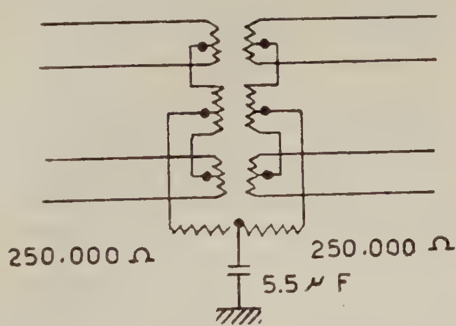


Fig. 6.

For this purpose, the metallic continuity at the gaps is restored for the transmission of D.C. test current without restoring the continuity for the induced longitudinal e.m.f. The device is shown on the preceding diagram (fig. 6). Two resistances in series connect the mid-point of the phantom transformers of each quad. The point of connection of the two resistances is earthed via a capacitance of such a value (5.5 μ F) that its impedance $1/\omega C$, approx. 580 ohm at 50 c/s, is completely negligible compared with that of the enclosing resistances.

only be carried out by means of intermediate relays.

In this connection, it is relevant to recall that the solution consisting in the connection across a transformer has also been found very useful where a spur line of some length is connected; in that case, the ratio is chosen so as to match the impedances of the circuits.

As regards the protection of cabled circuits against overcurrents and overvoltages, the tendency is not to use such protections for circuits running entirely in cables. This

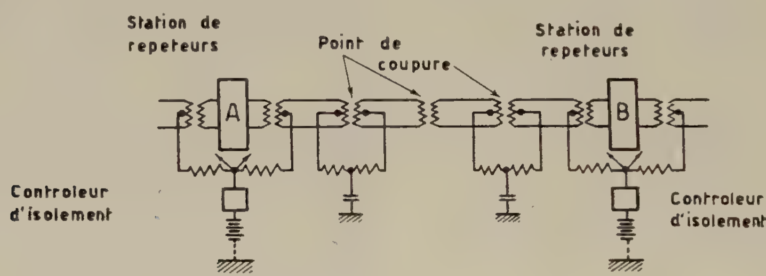


Fig. 7.

Explanation of French terms :

Contrôleur d'isolement = insulation control device. — Point de coupure = cutting point. — Station de répéteurs = repeater station.

The general connection scheme is that shown in figure 7.

The solution of systematic sectionalisation is not always necessary. Similar sectioning exists, in any case, at repeater stations at spacings which still provide a limitation of the induced voltages.

By inserting a translator between the circuit and the terminal equipment, it is possible to obtain better conditions for the whole circuit so that this solution must be regarded as highly advantageous provided, of course, that its application is practicable.

The solution of systematic sectionalisation, described above, could also be adopted for circuits other than telecommunication circuits if this is justified by their length, provided that they are A.C. circuits. Otherwise, sectionalisation could absence of special protection is particularly justified where the cabled circuits terminate in translators.

On the other hand, special protective devices are called for at points where an overhead line is connected with a cabled circuit.

CHAPTER III.

SIGNALLING AND TELECOMMUNICATIONS.

3.1 and 3.111. — Effects and disturbances observed.

The effects caused by the fundamental frequency or by harmonics can be grouped broadly under the following three headings:

1) *by direct action* on the installations connected to the track due to the presence of the return current in the rails, the non-negligible impedance of the rails, and their variable insulation against earth.

   In general, the track circuits are the only circuits liable to be disturbed by direct action;

2) *by magnetic induction :*

   a) on the installations connected to the track (track circuits) because of the parallelism of rails and catenary, and because of the parellelism of the rails of the two adjacent tracks;

   b) on the line installations where the length of the conductors running parallel to the catenary or to the rails exceeds a certain value;

3) *by electrostatic induction* on the installations situated in the vicinity of the catenaries and not separated from the latter by metallic screens.

   The disturbances observed are, however, not very important, and many disturbances that have been encountered have been eliminated by an improvement of the symmetry in relation to the earth of the installation; lack of symmetry, even if it occurred at particular points, gave rise to a fairly important overall unbalancing effect.

   Few quantitative data have come to hand as regards the noise voltages observed. The *N.S.* mention measurements carried out over the range of frequencies from 100 to 30 000 c/s which show that, under normal working conditions of the electric D.C. traction equipment, the maximum noise voltage does not exceed 0.7 mV.

   In any case, these values are always greatly reduced as a result of judiciously chosen arrangements of the installation and do not interfere with the working of the installations.

3.112. — Dangers.

From a danger point of view, the following distinction can be made :

a) danger to personnel, arising if the voltage in relation to earth exceeds a certain value which is not specified but which, with certain Administrations, is of the order of 100 V;

b) risks concerning the durability of the equipment if the voltage of a conductor in relation to the mass becomes incompatible with the dielectric strength of the insulating materials used;

c) risks concerning the proper working of the equipment if the voltages occurring between certain conductors are liable to cause untimely operation contrary to safety requirements, or modifications of the working characteristics of the apparatus outside the permissible tolerance limits (generally not incompatible with safety requirements).

In general, it can be stated that the three types of risks listed above can be reduced by a suitable arrangement of the installation, especially by limiting the length of parallelism of the metallic circuit concerned in relation to the catenary, and thus keeping within permissible limits the voltages which are liable to occur.

With the use of sectioning translators in the telecommunication circuits, the risks can be reduced to an altogether negligible value, even under the most unfavourable conditions of the electric traction equipment (e.g. if the circuit breakers are tripped).

3.12. — The regulations in force concerning works on the telecommunication circuits are fairly variegated and are influenced by the installation arrangements designed to minimize the magnitude of the voltages.

Among the precautions prescribed by the different Administrations are the use of rubber gloves and insulated pliers and, sometimes, insulating cloth.

In general, however, it can be confirmed that it is the installation arrangements which, in this connection, play the most important part in reducing the voltages to which the personnel may be exposed during the work.

However, where a fairly close distance between the catenary and the cable is liable to give rise to voltages dangerous to personnel required to carry out urgent repairs, special precautions are called for.

In this connection, it is relevant to mention the method used by the *S.N.C.F.* for works on telephone cables close to an energized catenary system.

In this case, the first step is to ensure, by means of temporary by-pass connections, the metallic continuity of sheath and armouring at the point where it might be necessary to cut them in order to lay bare the conductors. Earthing clamps are placed on the latter on either side of the point at which work is to be carried out, so that this work can then be carried out with bare hands. In restoring the cable, the process is reversed.

This method has been submitted to C.C.I.F., who are considering it.

In most cases, however, there is no need for any special measures on signalling circuits because of their fairly limited length.

No important accidents have ever been known to occur either with telephone installations or with signalling installations.

3.2. — Corrosion phenomena due to return currents.

It is well known that the risks of corrosion due to return currents are almost exclusively encountered on D.C. electrified lines. On A.C. electrified lines, the problem is almost non-existent in practice although it is still the subject of studies and research.

On most networks, the protection used for the lead sheaths or armouring (if any) of the telecommunication and signalling cables placed along the electrified railway takes the form of a passive protection obtained through insulating these metal structures against earth my means of rubber insulating sheaths or special tape material made of impregnated glass fibres. The problem can also be solved by using cables with sheaths made of thermoplastic materials. This can always be done in the case of local cables, e.g. those for signalling installations. On this subject, tests have been carried out on an important scale which have given most encouraging results.

The most difficult case is that of very long cables where it is difficult to keep a check on the insulation conditions, especially if the lead sheath or armouring are sectioned by isolating joints or sleeves.

Such a check on the insulation is necessary because, even in the case of protective measures carried out with good materials, and by methods ensuring a long service life (e.g. protections through application of resin) the sheath might still be affected by extraneous mechanical actions or by insects.

In this case, the measures to be carried out periodicially are fairly laborious and costly. At the same time, the screening effect for the conductors is considerably reduced by the sectionalisation referred to above, and by the insulation of the armouring or the metallic sheath of the cable in relation to earth.

It follows that passive protection alone is not always able to solve the problem and that, in most cases, the use of various types of cathodic protection is called for. It is interesting to note, in this connection, that Administrations which have up to now relied on passive protection alone are beginning to take an interest, for the reasons just stated, in the protection by polarised drainage or in cathodic protection connected to the rails.

In view of the fact that the effects to be feared vary greatly with the nature of the soil and with many local circumstances, it would seem possible reliably to ascertain the need for cathodic protection by comparing the results of measurements of the

voltage between the sheath (or armouring) of the cable and the soil, carried out before and after electric traction has been introduced.

The solution of the problem is liable to give rise to special difficulties if there are, close to the cable to be protected, metal structures such as water mains, gas mains or pipelines liable to be damaged either by the traction currents or arising from the new electrical conditions created by the application of the protective measures.

In such cases, which may occur fairly frequently in the vicinity of large cities or industrial districts, a judicious coordination of these protective measures is indispensable, calling for collaboration and agreement between the subsoil users.

However, the protective measures of this kind would only be fully effective if adequate arrangements are made with a view to reducing as much as possible the current leakage from rails to soil.

It is well known that, in order to achieve this result, the following measures must be taken :

a) to reduce as much as possible the electric resistance of the track, calling for very effective bonding.

It may be recalled in this connection that the electric resistance of any electric bonding at the joint between two rails must not exceed that of one metre of rail outside the joint. This condition is not always easy to fulfil, even with soldered connections, if it is desired to avoid, for practical reasons, the use of unduly large cross-sections. The choice of connections is also influenced by maintenance considerations because these connections are liable to be broken on the occasion of permanent way works or as a result of mechanical shocks, etc.;

b) to obtain the best possible insulation of the rails in relation to earth (i.e. the smallest possible leakance).

This insulation, advantageous in regard to the working of the track circuits, does however present difficulties in the case of tunnel sections or in cuttings with imperfect drainage.

It must not be overlooked, either, that a very effective insulation against earth might also give rise to such important rail-earth potentials that danger to the staff could not be ruled out where due to a fairly intensive traffic of heavy trains, the traction currents are very heavy.

The need of ensuring the best possible insulation between rails and earth may lead to a reduction in the number of connections between the supporting structures of the catenary and the rails.

In these cases, another need must be taken into consideration, viz., that of ensuring, in all cases, that the resistance of the return circuit is reduced as much as possible so that the differences in the rail-earth potential which might arise in the event of a breakdown of a catenary insulator are not detrimental to the safety of the staff, and to the correct working of the circuit breakers in the adjacent substations.

As with many other technical problems, a perfect solution does not exist, and it is necessary to look for a compromise solution. Among the possible solutions, that consisting of the use of discharge gaps in the connections between masts and rails undoubtedly presents advantages. It is, however, a costly solution as far as the installation is concerned, and calls for a close check on the insulation normally provided by these devices as these gaps are able, due to a discharge or for other reasons, to maintain a direct permanent connection between masts and rails.

Another possible solution consists in connecting, by an earth wire with the lowest possible electric resistance, all the poles with each other without connecting them with the rails.

The same considerations apply as regards the connection, with the rails, of the metal cabinets of the signalling relays,

the signal masts, etc., which should be provided for staff safety reasons and which, incidentally, represent more or less important leakage points for the return currents circulating in the rails.

Opinions on this subject are fairly divided, and final conclusions do not seem possible. Some Administrations systematically resort to the type of connection just described (*S.N.C.B.*), other do not do so (*F.S.*).

The choice of the solution to be adopted depends on many factors and, as in many other technical problems, might be facilitated by having recourse, as necessary, to the notion of the probabilities of a series of events.

3.3. Relevant data.

3.31. Signalling systems.

Preamble.

The opinion expressed in the preamble of the questionnaire that it is necessary to take into account the induction effects between a track circuit and the catenary of the adjacent track, or rather the rails of the adjacent track, is shared by the *S.N.C.F.* who have put forward very interesting considerations throwing fresh light on a question which, up to now, has not yet been sufficiently studied.

It is thought worth while quoting this section of the *S.N.C.F.* reply « in extenso » :

« We agree that, in studying the track circuits, it is of great importance to take into account the degree of unbalance of the traction currents which may occur between the two lines of rails.

In the case of D.C. traction, this unbalance results mainly from a difference in the ohmic resistance of the two lines of rails or from a difference in the insulation of these rails in relation to earth, and can therefore be easily evaluated.

In the case of A.C. traction (50 c/s), however, it is necessary to distinguish between :

1) the unbalance due to the traction current;

2) the unbalance due to the current induced by the catenary of the adjacent track, and

3) the unbalance due to the current induced by the return current circulating in the lines of rails of the adjacent track.

We shall deal with each of these three effects in turn.

1) *Unbalance due to the traction current.*

The type of unbalance listed under 1) can only arise from a marked difference in the insulation of the two lines of rails, due in particular to an unwanted earth on one of the lines. The effect of the difference in longitudinal impedance is relatively unimportant in view of the preponderance of the reactive component over the resistive component (fig. 8).

The degree of unbalance increases during the approach and passing of a train; but it is very low if there is no train in the vicinity.

This unbalance may occur on single-track lines as well as on double-track lines.

As a remedy, it is necessary to ensure that the insulation of both lines of rails is, as far as possible identical.

The cross-connection of the lines of rails is apt to restore a certain equilibrium. In numerous cases, however, this measure has little effect as the insulation per unit of length of each of the rails is generally not constant.

2) *Unbalance due to the current induced by the catenary of the adjacent track* (fig. 9).

This type of unbalance can only occur on double-track lines and results, as stated, from the lack of symmetry of each of the rails-earth loops of the track in relation to the catenary-earth loop of the adjacent track — a lack of balance which gives rise

to different values of the mutual inductance between the catenary of No. 1 track on the one hand, and each of the lines of rails of No. 2 track on the other hand.

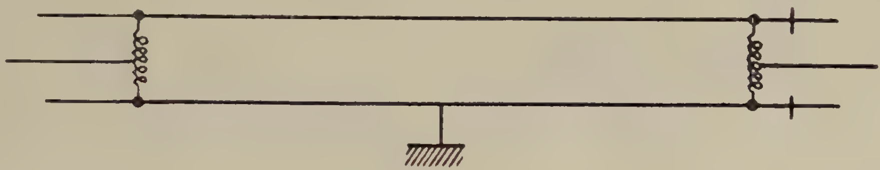


Fig. 8.

This unbalance is independent of the position of the trains on No. 1 track, and depends on the traffic at a given moment.

A cross-connection of the lines of rails at the mid-points of the insulated sections can be effective.

When a train approaches the section concerned on the parallel track, the return current-except in the immediate vicinity of a substation — is divided into two virtually equal parts on either side of the locomotive (cf. fig. 10), and each of these part-currents tends to induce in the adjacent track (No. 2 track in the drawing) two currents in opposite directions.

It follows that, as and when the train

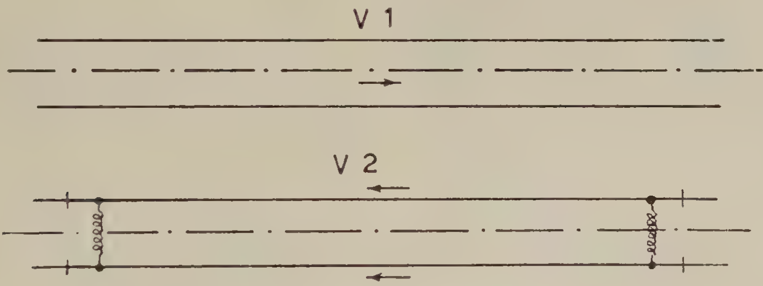


Fig. 9.

3) *Unbalance due to the current induced by the lines of rails of the adjacent track* (fig. 10).

The single-pointed arrows indicate the direction of the inducting current, the double-pointed arrows the direction of the current induced in No. 2 track (V2) while a train approaches on No. 1 track (V1), and the treble-pointed arrows the direction of the current induced in No. 2 track (V2) when the train on No. 1 track (V1) reaches the point B′.

proceeds on No. 1 track, the current induced in the track circuit of No. 2 track will first increase and then decrease, and will disappear when the train is close to the mid-point of the section. The current is then reversed, and subsequently reduced, and will finally disappear as the train moves away from the section (cf. fig. 11).

As it happens, the unbalance current caused by the unequal induction in the two lines of rails of No. 2 track as a result of the current in No. 1 track, undergoes

practically the same variations as the induced current.

If there is no train about, the unbalance is zero.

However this may be, the question is extremely interesting and deserves to be studied in detail with the aid of systematic measurements and surveys.

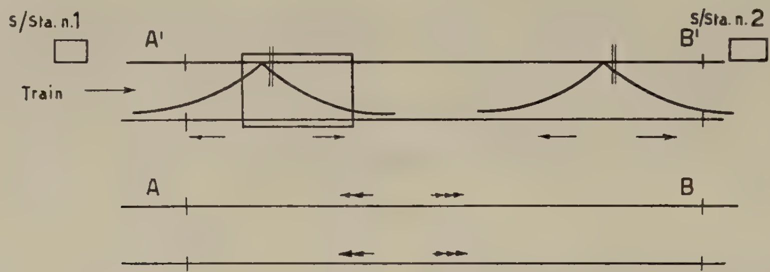


Fig. 10.

The cross-connection of the lines of rails does not solve this problem.

It may be added that the theory outlined above has been wholly corroborated by practical experience but that, so far, it has not been possible to obtain, by means of tests, any precise values of the degree of unbalance in the different cases considered.

The *D.B.*, too, state that induction effects are liable to occur but the values measured for the induced currents are altogether negligible.

Apart from the *S.N.C.F.* and *D.B.*, no other Administration has expressed an opinion on this subject.

3.311. — D.C. electrified lines.

3.311.1. — The length up to which single-rail track circuits are used varies considerably as between one Administration and another.

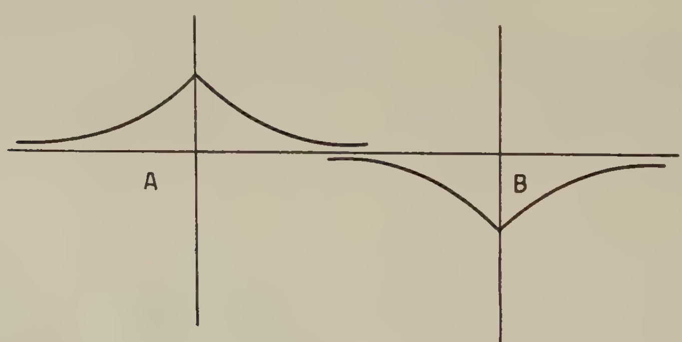


Fig. 11.

Some particulars on this subject are given below :

D.B. — 200 m.

S.N.C.B. — 400 m on double-track lines outside the stations, 800 m in stations.

R.E.N.F.E. — 250 m.

C.F.F. — 400 m (on the La Plaine-Geneva line, 1 500 V D.C.).

S.N.C.F. — 400 m.

The limiting criterion is the voltage liable to produce a circulation current in the equipment and a deterioration of the latter (through heating and saturation of the transformers).

Also, the principle of the detection of broken rails, which is an *S.N.C.F.* standard practice, precludes the general application of single-rail track circuits on lines used by fast trains.

R.A.T.P. — 50 m (used exceptionally).

F.S. — 900 m, mostly in stations.

N.S. — 700 m.

P.K.P. — 100 m.

The remarkable differences between the maximum lengths permitted by the different Administrations are understandable if the limiting criteria governing the installations are considered.

In fact, the traction return current which passes through the line of rails to earth gives rise to a difference in potential on the insulated line of rails due to the ohmic resistance between the two points where the feeder and receiver equipment are connected. This difference in potential gives rise, in its turn, to a current which flows in the feeding and receiving equipment and which is liable to cause heating and saturation effects, etc., in the equipment.

Now, the return currents obviously depend on the load absorbed by the locomotives and on the voltage in the catenary, and are the lighter the higher the voltage. That is why the limitation in length is less stringent on systems with higher voltages. As regards the ohmic resistance between the two points where the feeding and receiving equipments are connected, this resistance is obviously highest on single-track lines, where the traction current can only use one line of rails for the return to earth, whilst it is lowest in the stations where the current can use several parallel lines of rails.

The principle of rail fracture detection may entail limitations in the use, even in principle, of this type of track circuit.

3.311.2. — On D.C. electrified lines, the track circuits are, in principle, fed by A.C. of a frequency which is either the normal supply frequency or a different one.

Current of industrial frequency is used by the following Administrations:

D.B., S.N.C.B., R.E.N.F.E., R.A.T.P., Moroccan Railways, F.S., N.S., P.K.P. — Current of industrial frequency or a different frequency is used by the following Administrations:

- *S.N.C.F.* where, as a general rule, the track circuits on D.C. electrified lines are fed by 50 c/s current, but use is also made of audio-frequency circuits or, where the shuntage by the axles causes difficulties, of track circuits with high-tension impulses;
- *Algerian Railways* where the use of industrial frequencies is confined to cases where the installations is important enough to warrant the provision of an auxiliary generating set; otherwise, the frequency is 1 500 or 2 000 c/s and, in certain cases, even 20 000 c/s;
- *C.F.F.* where the normal industrial frequency of 50 c/s is never used; the frequencies used here are either 42 c/s obtained from a rotary converter set, or 1 000 c/s obtained from an electronic oscillator.

3.311.3. — The use of D.C. track circuits is altogether exceptional and limited to very short circuits.

This is the case on the following networks :

D.B. — D.C. circuits of 12 V for lengths up to 30 m.

S.N.C.F. — Some D.C. track circuits of a length ranging from 18 to 50 m have been installed for the release of unguarded level crossings. This practice will not be continued in view of the excellent results obtained with track circuits with frequencies ranging from 3 700 to 10 000 c/s which, when used for the same purpose, also offer the advantage of not requiring isolating joints.

P.K.P. — For insulated rails of up to 30 m length, in conjunction with rail contacts.

None of the other Administrations ever use D.C. track circuits on D.C. electrified lines.

3.311.42. — As regards the influence of the harmonics of the rectified electric traction current, most of the Administrations use, for track circuits fed with industrial frequency, induction relays with two de-phased elements, which completely eliminate any danger of untimely working of the circuits.

Where rectifier relays are used as in some earlier installations of the *F.S.*, a limitation of the length of the track circuits is imposed.

On the *C.F.F.*, the question does not arise as a feed from the network frequency is never used.

3.311.43. — This possibility is not envisaged by any of the Administrations in view of the fact that the case of a line being fed by a single rectifier is only encountered very rarely. In any case, with the use of relays with two elements, an unwanted excitation could only take place in the case of quite specific phase relations between the current in the rails and the current in the local element, even if the frequency is the same.

On the *R.A.T.P.*, the feed of any rectifiers where one anode has become inactive is automatically cut out, and this fact is indicated by pilot lights at the control centre.

3.311.44. — As already mentioned under 3.311.42 above, the Administrations nearly always use relays with two elements (of the motor or vane type).

Exceptions are some applications of insulated rails associated with rectifier relays (*S.N.C.B.*), and track circuits of limited length with the older installations of the *F.S.*

Some Administrations (*S.N.C.F., S.N.C.B.*) use circuits with high voltage impulses where the axle shuntage conditions present difficulties. In that case, the relay used is a D.C. relay of the simple or differential type.

3.311.45. — The track circuits which, as mentioned above, use relays with two de-phased elements sometives have a two-phase feed (one phase for the track circuit element and one for the local element of the relays), sometimes a feed obtained through transformers on two different phases of a three-phase network, and sometimes a feed from a single-phase alternating voltage for both elements.

3.311.46. — Certain Administrations have no misgivings regarding the problem of operating regularity which consists in preventing any untimely dropping of a single rail track circuit relay when the track circuit is not occupied, due to saturation effects produced by the return currents.

Among these Administrations are :

D.B., R.E.N.F.E., R.A.T.P., Algerian and Moroccan Railways, P.K.P.

Other Administrations make use of resistances inserted in one of the connections between the rails and the output transformers : *S.N.C.B.* and *C.F.F.*

The *S.N.C.F.* have, in this respect, resorted to the following three measures :

a) limiting the length of the track circuit;

b) adopting an adequate rating for the

equipment concerned, having regard to the maximum length permitted (non-saturable transformer);

c) using current limiting resistances as mentioned above.

The *F.S.* resort to limiting resistances (fig. 12) for those track circuits where rec-

In their turn, the *N.S.* use for single-rail track circuits the device known as « balancing impedance » (figs. 14*a* and 14*b*).

With this device, the track element of the relay comprises two windings which have the same ohmic resistance and the same number of turns. The external terminals of the track element are connected

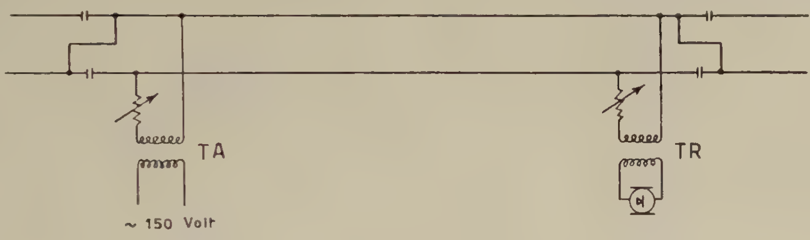


Fig. 12.

tifier relays are used. In the case of circuits where relays with two elements of the motor or vane type are fitted, the *F.S.* successfully use a bridge device where the balance in the D.C. system prevents this current from circulating in the primary winding of the output transformer,

to the terminals of the balancing impedance which comprises two sections with the same ohmic resistance, so designed however that one is, in practice, purely ohmic whilst the other is predominantly inductive. The conductors arriving from the receiving end of the track circuit are connected to

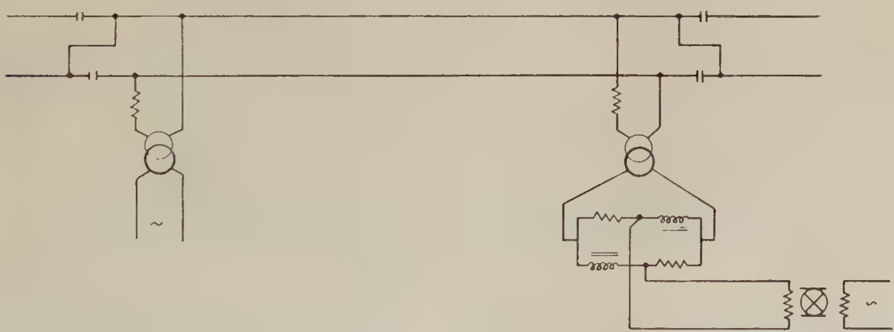


Fig. 13 (*).

and from causing the saturation of the latter (cf. connection diagram, fig. 13).

(*) *Erratum :* In this diagram (fig. 13), the receiver transformer should be inserted between the bridge device and the track element of the relay.

the intermediate points between the first and second section of the track element and the balancing impedance.

In consequence, the direct currents emanating from the track circuit are equally divided into the two halves of the track

element and do not give rise to any magnetising effect whilst the alternating currents give rise to resultant alternating flux causing the operation of the relay.

The *N.S.* take into account a total unbalance between the currents in the two branches of the impedance bond. In these circumstances, the variation of the impe-

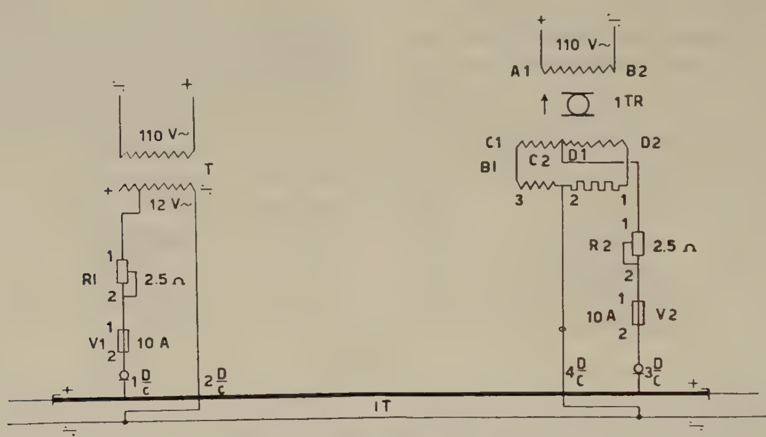


Fig. 14*a*.

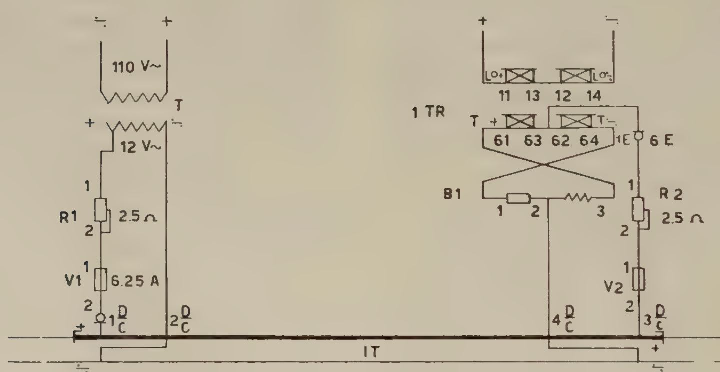


Fig. 14*b*.

3.311.47. — As regards the degree of unbalance between the currents in the two branches of the impedance bond connected to the two lines of rails, the only data obtained are these:

S.N.C.B. — Unbalance current: 500 A.

S.N.C.F., R.A.T.P., Algerian Railways: 12 %.

F.S. — 20 %.

dance of the bond must not exceed 10 %, and the track circuit must still work normally.

3.311.48. — The protective devices normally used are fuses, but discharge gaps are also used:

The *S.N.C.F.* use:

— on insulated circuits equipped with

impedance bonds : voltage fuses of 1 500 V type, a device which, in the case of equipment installed in a building, is supplemented by spark gaps connected to earth;

— on other track circuits, and especially on single-rail circuits : fuses without spark gaps; on single-rail circuits, a discharge gap is used if the length exceeds 100 m.

3.311.49. — In most cases, these protective devices are used in the same way irrespective of the length of the circuit, with the following exceptions :

— the *D.B.* use a single spark gap on circuits of less than 100 m length, but two spark gaps, located 100 m away from either end of the circuit, on longer circuits;

— the *S.N.C.F.* where the use of discharge gaps is limited to circuits of more than 100 m length;

— the *F.S.* where the use of spark gaps or voltage-limiting devices is confined to very long circuits fitted with impedance bonds.

In general, it can be concluded that :

a) relays with two elements provide a satisfactory protection against any disturbing influence of the harmonics of the traction current supplied by the rectifiers;

b) although necessitating certain limitations, single-rail track circuits may well be used with advantage, especially in stations, in all cases where the length of track to be covered is not too great. In this case, appropriate devices of the limiting resistance type or bridge type or balancing impedance type prevent any untimely dropping of the relay when the track circuit is unoccupied, due to the saturation effect produced by the traction currents;

c) where the length of track to be covered is fairly considerable, it is preferable to use a double rail track circuit with impedance bonds.

The critical length above which one might be inclined, even in the stations, to use circuits with impedance bonds rather than single-rail circuits is determined, on the one hand, by the limitations of single-rail circuits already discussed, and on the other hand, by economic considerations.

In this respect, the audio-frequency circuits where the impedance bonds are very small, offer a by no means negligible advantage.

3.312. — A.C. electrified lines.

3.312.1. — The lengths of single-rail track circuits on A.C. electrified lines permitted by the various Administrations differ considerably.

Many Administrations use track circuits with a D.C. feed from a floating accumulator battery connected to a transformer-rectifier which is served by an A.C. feeder. The maximum lengths are as follows :

Ö.B.B. — Normal length of track circuits used in stations.

D.B. — 800 m.

C.F.F. — 2 000 m.

Rhaetian Railway. — 200 m.

S.N.C.F. — 1 000 m, provided that the soil currents do not exceed 1 A.

The *F.S.* permit a maximum length of 900 m and use, for the track circuits, either a D.C. feed (by means of floating batteries connected to a transformer-rectifier) or an A.C. feed (see below).

3.312.2. — Many Administrations use for their D.C. track circuits protective resistances or chokes with an impedance which is sufficiently high at the traction current frequency used. The resistances or chokes are, in most cases, inserted either on the feeder side or on the receiving side.

The D.C. relay is nearly always chosen with special characteristics which ensure a

fairly high actuating value for an alternating voltage at traction current frequency.

In many cases, a purely ohmic resistance is connected parallel to the relay, shunting the winding in respect of the A.C. and causing a decrease of the alternating voltage which is liable to appear at the terminals of the track relay.

The D.C. relays used for this purpose often have windings with a fairly high ohmic resistance which, all other things being equal, gives rise to an increase in the actuation voltage within limits which are, however, not troublesome.

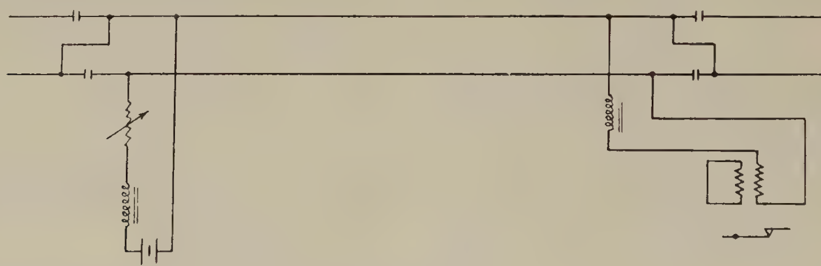


Fig. 15.

As far as the application of these measures is concerned, the different Administrations can be grouped as follows:

a) use of protective resistances or chokes only: *C.F.F.*;

b) use of protective resistances or chokes as well as other devices described above (special D.C. relays, but without parallel-connected ohmic resistance): *F.S.* (cf. fig. 15);

c) simultaneous use of all the measures described above: *S.N.C.F.* (cf. fig. 16).

Where special relays are used, these merely consist of D.C. relays equipped with short-circuit rings (*S.N.C.F.*) or short-circuit windings (with a single turn per core) which give rise to a very high actuating voltage of the relay if it is fed with A.C. at traction current frequency.

This device is useful also from a service regularity point of view inasmuch as it prevents disturbing vibrations of the relay armature while the circuit is unoccupied, which are caused by the traction current and might lead to untimely openings of the contacts. On the other hand, this measure unavoidably entails a certain time lag in the working characteristics of the relay which does not, however, cause any trouble.

Within certain appropriate limits, the resulting higher value of the potential between the two lines of rails is able to bring about an improvement in the shunt conditions.

Such an increase, which is associated with a greater number of turns of the relay winding, will obviously also increase the self-impedance of the latter (which is proportional to the square of the number of turns); this affords a useful protection against the harmful effects of the traction currents.

The conditions resulting from all the measures described above give rise to actuating voltages of the A.C. relay at network frequency which amount to some hundreds of volts. These favourable conditions can obviously be obtained more easily by choosing higher traction frequencies.

3.312.31. — In choosing the feed frequency of the track circuits, all the Administrations take into account not only the fundamental frequency of the traction current but also the frequency of the harmonics. The frequency is so chosen that it is as far as possible from the

above frequency values in order to obtain a sufficiently great safety margin.

As regards the harmonics which should be taken into account, it is, first of all, necessary to distinguish between harmonics of odd and even order, respectively.

Where no D.C. is circulating in the rails, i.e. everywhere except at stations equipped for two or more systems, it is only necessary to take the odd harmonics of the fundamental traction frequency into account. Thus, the *D.B.* use for track circuits on lines electrified for single-phase A.C. of 16 2/3 c/s, a frequency of 100 c/s which is situated between the 5th and 7th harmonic and coincides, as it happens, with the 6th harmonic of that fundamental frequency.

The *S.N.C.F.* have chosen, for their single-phase A.C. 50 c/s lines, a frequency of 83 1/3 c/s which is situated between the fundamental traction current frequency and its 2nd harmonic. In this way, this solution is also acceptable in the case of stations equipped for single-phase as well as D.C. traction. This frequency is obtained by means of rotary converter sets which feed a whole installation.

A more recent solution adopted by the *S.N.C.F.* consists in using current with frequencies of 350, 800, 1 500 and 2 000 c/s where the two former are in addition modulated « all or nothing » at 14 and 20 c/s, respectively. The frequencies adopted are therefore far removed from the fundamental frequency of 50 c/s and even if they coincide with (fairly high) harmonics of that frequency, the « all or nothing » modulation used introduces a further safety element and prevents any risk of an untimely excitation of the relay.

These frequencies are obtained by means of individual electronic oscillators, one for each circuit. The four frequencies chosen are fairly far removed from each other in order to obtain a perfect solution of the problem of the bridged joint between two adjacent circuits without using phase relations which would, in this case, not be determined. Owing to the fact that four different frequencies have been adopted, it is possible to make sure that, in any case, however complicated the installation may be, two adjacent circuits are never fed with currents of the same frequency — this is the classic problem of topology known as « colouration of geographical maps ».

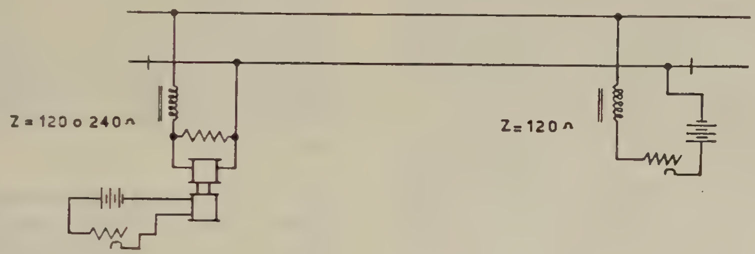


Fig. 16.

On the three-phase 3 600 V 16 2/3 c/s network of the *F.S.*, two different cases are encountered.

The first case is that of normal electric locomotives with motors connected to the contact line without the interposition of transformers.

As far as the track circuits are concerned, the harmonics to be taken into account in this case are obviously those of odd order. It must be pointed out that, in general, the harmonics do not appear in the wave form of the traction load current but appear in the secondary of the transformers con-

nected to the two lines of rails, as a result of the saturation phenomena of the magnetic cores.

The feed frequency adopted for the track circuits is 75 c/s, a value situated between the 4th and 5th harmonic of the traction currents, so that, even in stations with mixed traction system where the possibility of even-order harmonics is present, there is always an adequate safety margin. In fact, with the type of track relay used, a difference of 2 c/s between the frequencies feeding the local element and the track element is sufficient to prevent any pendular movement of the relay armature.

A second interesting case is encountered on the *F.S.* network with the so-called dual-current railcars which work both on the three-phase 3.6 kV, 16.7 c/s system and on the 3.4 kV D.C. system.

When running on the three-phase system, the contact line feeds, across a transformer, excitrons yielding a rectified current which feeds the D.C. traction motors. When running on the D.C. system, the motors are directly connected to the catenary.

In this case, the current absorbed from the three-phase contact line will obviously contain considerable harmonics of the 5th and 7th order.

The system chosen has thus been found satisfactory.

3.312.33. — It is usual to take into account by different means, transient phenomena which might give rise to currents with frequencies in bands outside the normal frequency and its harmonics, and this at the rate normally admitted.

In this respect, « all or nothing » modulation of the track circuit feeder currents provides an additional safety element of great importance even if, due to transient phenomena, there should be a coincidence of the traction current frequency and the carrier frequency of the track circuit feed (*C.F.F., S.N.C.F.*).

Another device used for this purpose consists in the systematic application of a repeater relay with a time lag of one second in relation to the track relay. This relay prevents any transient excitation of the track relay from affecting the indication of the signals.

Neither with the *D.B.* nor with the *F.S.* have any special measures been taken for this purpose.

3.312.4. — As far as the currents absorbed by rectifier locomotives are concerned, the *S.N.C.F.* merely take the odd harmonics into account. Harmonics of an order above the 15th are present at rates below 1 % and can therefore be neglected.

The dual-current railcars of the *F.S.* mentioned earlier on are, in practice, in the same category as the rectifier locomotives. The problem has been solved by a suitable choice of frequency.

3.312.51. — According to the explanations given in the preceding paragraphs, the following solutions among those adopted provide for a track circuit feeder frequency which is higher than the fundamental traction frequency :

D.B. — Between the 5th and 7th harmonic.

C.F.F. — With the 42 c/s solution as well as with the 1 000 c/s solution.

S.N.C.F. — With the 83.3 c/s solutions as well as with the 350, 800, 1 500, 2 000 c/s solutions.

F.S. — Between the 4th and 5th harmonic.

A solution where the track circuit feed frequency is lower than the traction current frequency is that adopted by the *S.N.C.F.* with high-voltage impulses. In this case, the frequency of the high-voltage impulses is 3 c/s, i.e. well below the fundamental frequency of the traction current.

Whether the track circuit feed frequency should be below or above the fundamental traction current frequency is a matter of opinion.

In principle, the choice of a frequency in the range below the fundamental would have some advantages: the impedance of the transmission circuit, formed by the two lines of rails, would thus be much reduced, and any chance of coincidence with the traction frequency or its harmonics would be eliminated. On the other hand, the generating devices become heavy and unwieldy, and the working of the induction relays becomes less satisfactory.

The contrary is the case if the other frequency range is chosen. In this case, the circuit impedance is higher, it is necessary to choose a frequency between two harmonics of successive order, and if it is desired to obtain a sufficiently wide safety margin, one is forced to turn to fairly high frequencies. On the other hand, the feeding and receiving devices become smaller and more economic, and the feeder currents can be produced by means of electronic, i.e. absolutely static, devices so that it is possible to forgo continuously working rotary sets which give rise to practical objections.

Moreover, as has been pointed out, it is possible with fairly high frequencies to resort to the pulsation or modulation of the carrier frequency so that a further safety element is introduced.

That is how the fairly wide differences in the principles followed by the different Administrations can be explained. It can be foreseen, however, that as a result of the present trend towards a more and more extensive use of electronic devices, the application of audio-frequencies will increase.

It must not be overlooked that, as is well known, these devices have two great advantages as far as track circuits are concerned.

The first consists in the possibility of using generators (oscillators) which have an external (terminal voltage-current output) characteristic of a form permitting to obtain a very accurate threshold of operation, and more advantageous than the characteristic obtained with ordinary generators associated with limiting impedance.

The second advantage obtainable with frequencies of the order of 8 ÷ 10 K c/s is that it is possible to forgo any isolating joints; this entails very important practical advantage in many cases (long-welded rails, etc.).

3.312.52. — Modulated frequencies are used by the following Administrations: *C.F.F.*, *S.N.C.F.* (see preceding paragraphs).

The *F.S.* operate two important automatic block installations with track circuits fed by A.C. of industrial frequency (50 c/s) which is coded, i.e. periodically interrupted. There are thus periods of current transmission (« on time ») and periods of current interruption (« off time ») which are, in principle, of equal length. If the total period is understood to include the sum of the « on » and « off » times, i.e. twice the duration of each of these times, the frequency of repetition is 75, 120, 180 per min, i.e. 1.25, 2 and 3 c/s, respectively.

This type of circuit arrangement has been used not so much in order to obtain a protection against the harmful effects of traction currents but rather in order to provide the non-occupied track circuit with several different indications determining the indication given by the signal, and to eliminate any possibility of faulty indication of non-occupied track due to the track relay sticking or being otherwise out of order.

Such coding is, however, also useful as a safety precaution against the harmful effects of the traction currents, and even against the effects of alternating currents which result from earth leakages from the industrial network and might be trespassing on the rails.

The system mentioned above is used on the Bologna-Florence and Rome-Naples lines. The equipment of the former line has been provided by the « General Railway Signal Company » (G.R.S.) of Rochester (U.S.A.), and that of the latter by the « Union Switch and Signal Company » of Swissvale (U.S.A.).

The coding is obtained by means of elec-

tro-mechanical devices known as coding relays which can provide one of the three cadences mentioned above. In all cases, the carrier current has the industrial frequency of 50 c/s.

The length of the track circuits used may reach 1 800 to 2 000 m.

3.312.53. — It can be stated as a general conclusion that the track circuits in use are so designed that safe conditions are ensured even in the event of abnormal conditions in the traction system and that, in the case of very heavy damage, the relay will, at most, tend to drop.

If upper limits are set in respect of the degree of unbalance of the traction currents in circuits equipped with impedance bonds, this is merely done in order to preserve regularity of operation and to improve the performance of the equipment, and not for safety reasons.

3.312.6. — Protection against major overvoltages which might occur in the circuits equipped with impedance bonds in the event of a complete interruption in one line of rails is obtained, in certain cases, by spark gaps or discharge gaps (*D.B., C.F.F., F.S.*) connected to the low current (secondary) winding of the impedance bonds. In other cases, it is obtained by a judicious arrangement of the installation, capable of limiting the voltage which might arise in the case assumed above (*S.N.C.F.*).

If, in the case of this second solution, the track circuits have a frequency of 83.3 c/s, the impedance bonds (which do not embody secondary windings) are used in conjunction with track transformers which will be saturated by an alternating current exceeding 10 A.

With this arrangement, the voltage at the track transformer terminals and, consequently, that of the track relays and the current supply is automatically limited in the event of a total unbalance resulting from the interruption of one line of rails. Moreover, the installation is protected against overcurrent by a fuse series-connected with the « thick-wire » (primary) winding of these transformers.

With other types of track circuits, the overvoltage at the terminals of the impedance bonds is limited by the fairly low impedance of the latter in relation to the frequency of 50 c/s (being of the order of 1/10th of an ohm). Moreover, the characteristics of the apparatus used are such as to admit a certain overvoltage which is liable to appear at the impedance bond without being able to exceed some 10 to 20 V on the « bar » side.

3.312.7. — The *D.B.* use resonant circuits in order to reduce the losses in the circuit. The same applies to the *C.F.F.* and *F.S.* The same principle has also been adopted by the *S.N.C.F.* for the electronic track circuits where the impedance bonds are so tuned as to bring about a marked increase in the value of the impedance connected between the rails on the transmitter side as well as on the receiver side.

This precaution is not absolutely necessary in the case of circuits fed with 83.3 c/s where the impedance of the impedance bonds is already fairly high at that frequency. Also, with this type of circuit, this precaution is not taken on the feeder side.

In the case of track circuits, with voltage impulses, the impedance of the impedance bonds is sufficiently high to obviate the need for using a resonant circuit.

3.312.8. — The types of track relay used are as follows :

Ö.B.B. — Motor type relay.

D.B. :

1) A.C. track circuit relays :

  a) relays with two elements (of the motor type) with two positions at the frequency of 100 c/s.

  Local element : 180 V (38-39 mA).

Track element : 21.5-26 V (11.5-13.1 mA).

b) relays with two elements (of the motor type) with three positions at the frequency of 100 c/s.

Local element : 180 V (40-42 mA).

Track element : 24.7-27.2 V (12.6-13.2 mA).

2) D.C. track circuit relays :

Resistance of the winding : 53.5 ohms;
Normal feed current : 23.5-25 mA;
Actuating current limit : 25.3 mA;
Release current limit : 16.6 mA.

C.F.F. :

a) for 42 c/s circuits : Siemens relays with two elements;

b) for 1 000 c/s track circuits : normal single-contact signalling relays.

S.N.C.F. — For track circuits fed with 83.3 c/s : vane relays with two elements.

The track circuits are fed by two-phase current, one of the phases serving to feed the local relay element and the other the track circuit. The relay is actuated by a voltage of 40 V on the track element, and released by a voltage of 30 V, whilst the local element has a 115 V feed.

On electronic track circuits, use is made of a special valve receiver capable of detecting, amplifying and rectifying the pulsated voltages received. The more or less continuous voltage supplied by the receiver concerned is applied to an ordinary 400 ohm D.C. relay (actuating current 7.5 mA, release current 5 mA).

On impulse type track circuits, the *S.N.C.F.* use a system consisting of rectifiers and capacitance and a differential relay with two windings, so designed that the system is indifferent to an alternating current of 50 c/s and its harmonics.

F.S. :

a) for D.C. track circuits : D.C. 16 ohm relay with short-circuited solid winding;

b) with A.C. track circuits at the frequency of 75 c/s (+ 1 %, — 5 %) : relay with two elements of the motor or vane type with local element of 120 V, track element of 16 V (minimum actuating voltage; release at 9.5 V).

The problem of the choice of the relays to be used with track circuits on A.C. electrified lines is of the greatest importance in view of the fact that the judicious choice of the frequency of the track circuit feed would not, on its own, solve the problem of protecting the working of the track circuits against the effects of the traction currents, if it would not be possible completely to prevent the track relay from being actuated by currents of a frequency differing from that used for the normal track circuit feed.

It is apparent from the replies analyzed above that the solutions which can be applied can be classified in two categories.

In the first category are those using as track relays an induction relay with two elements (two-phase), comprising a local element which is fed directly from the A.C. supply at the frequency of the circuit, and a track element which is fed by the same supply at the same frequency across the track circuit.

It is well known that the means value of the motor torque on relays of this type will only differ from zero in the (normal) case where the feed frequencies are the same and where there are suitable phase relations between the currents circulating in the two elements. The relevant factors may be appreciated from the well known equation for the motor torque $C = K.I_L.I_V. \sin \varphi$ (where C is the motor torque, I_L the current in the local element, I_V the current in the track element, and φ the phase angle between the two currents); this still ignores several phenomena which also have an influence.

If, on the other hand, the currents in the two elements have a different frequency, the mean value of the motor torque is zero, but pendular oscillations of the relay armature (vane or even rotor type)

tend to occur at a beat frequency which is virtually equal to the difference of the feed frequencies.

It follows that, if these frequencies are fairly different from each other, the vane or rotor become virtually indifferent to these alternating torques; as soon as this difference amounts to some cycles per second (though there are some quite remarkable intervals, depending on the type of relay) the vibrations are so small that their effect can be ignored.

These considerations thus show that no current of the same frequency as the traction current liable to circulate in the track element, could give rise to a motor torque able to energize the track relay, or to keep it energized.

In practice, these considerations will only apply if there is no chance of currents at the frequency of the traction current circulating in the local element.

This entails the need for avoiding any coupling (conductive, inductive or capacitative) between the circuits feeding the two elements.

For this purpose, it is possible to use the following devices:

1) two phase alternator at the frequency chosen, with one phase feeding the local elements, and with the other phase feeding the track circuits and, through them, the track elements;

2) three-phase alternator with Scott transformer (three-phase-two-phase);

3) two single-phase alternators driven by the same motor and able to provide the chosen frequency on two circuits with two voltages with a phase difference of the order of 90° which can however be varied within a fairly small interval in order to obtain the most favourable conditions for the working of the circuits.

Solution 1) is used by the *S.N.C.F.* and *F.S.*

Solutions 2) and 3) have been used by the *F.S.* on certain installations on the three-phase A.C. 16 2/3 c/s system.

An altogether different solution consists in using filter circuits which preclude any chance of the track relays being actuated by currents of a frequency not coinciding with that of the track circuit feed. If the frequency of the track circuit feed has been judiciously chosen, i.e. if it is sufficiently removed from the fundamental frequency and the important harmonics of the traction current, this solution does not entail special problems as far as the provision of filters is concerned. The protection thus obtained cannot give rise to any objection from a safety point of view and may, in many cases, be preferable to the other solution, provided that protection is ensured against the effects of a possible failure of the joint between adjacent track circuits.

By choosing for each circuit a frequency from among the four frequencies of 350, 800, 1 500 or 2 000 c/s, a perfect solution can be found for this protection which is undoubtedly just as good as, if not superior to, the type of protection obtainable with conventional means.

Second category.

3.312.9, 91, 92, 93. — It can be stated as a general conclusion that, with the devices adopted by the different Administrations and described above, the traction current has no detrimental effect on safety, and there is no single instance in which the presence of the traction current would be able to cause the untimely operation of the relay.

As regards operating regularity, it can equally be confirmed that the effects of the traction current have been rendered virtually negligible.

The fracture of a rail on track circuits equipped with impedance bonds will tend to cause the dropping of the track relay.

3.313. — Stations with two or more electrification systems.

On the *D.B.*, this problem is not topical at present.

It will, in the future become topical for the *S.N.C.B.* in the case of certain frontier stations between the two systems: 3 000 V D.C. and 25 kV single-phase A.C. 50 c/s. For this case, the *S.N.C.B.* contemplate the use of impulse type track circuits of the kind described above which are suitable for use with these two traction systems and appear to be economic. It may however be necessary to reduce the length that can be permitted for single-rail track circuits.

The *C.F.F.* envisage for their stations the following two cases:

a) single-phase 16 2/3 c/s system and D.C. system;

b) single-phase 16 2/3 c/s system and single-phase 50 c/s system.

In case *a*), track circuits fed with 42 c/s are used, whilst D.C. track circuits are used in case *b*).

The same problem is encountered on the *S.N.C.F.* at a very small number of stations. Moreover, most of the tracks of these stations can only be used by one or the other of the types of current concerned (A.C. 50 c/s; A.C. 16 2/3 c/s, or D.C.).

In the very rare cases of « switch over zones » which can be used indifferently by D.C. or by 50 c/s A.C., use is made of track circuits of 2 000 or 1 500 c/s insulated on one line of rails only. This solution was possible because of the short length (less than 1 000 m) of the insulated sections concerned. In fact, this type of track circuit is, at the same time, indifferent to A.C. of 50 c/s and to D.C.

On the *F.S.* network, there are some stations equipped for two systems of electrification (D.C. of 3.4 kV; three-phase A.C. of 3.6 kV, 16 2/3 c/s).

The measures which have been taken in the case of stations or lines electrified with three-phase A.C. are also suitable in the case, here considered, of stations equipped for two traction systems; but all D.C. circuits, even very short ones, are systematically excluded.

The only track circuits used are those fed with 75 c/s A.C.

Actually, due to the direct currents which, in this case, flow in the track side windings of the feeding and receiving transformers of the track circuits, these windings are subjected to an unidirectional magnetisation. As a result, an alternating flux is encountered in the presence of the alternating currents flowing in the same windings; this flux has harmonics of even orders and gives rise to an alternating e.m.f. which also contains harmonics of even orders.

In other words, it is necessary, in this case, to take into account both the harmonics of odd and even order.

It has been demonstrated that the frequency chosen meets this condition well, and that it provides an ample safety margin.

3.32. — Other types of signalling circuits.

3.321. — Signalling circuits other than track circuits use insulated conductors in cables in fairly different types which are, however, designed to ensure the insulation of the conductors even under the most unfavourable conditions.

The section of the conductors is so chosen as to obtain, on the line, fairly reduced resistances compared with the resistance or impedance of the signalling equipment connected to the end of the circuit.

As a further precaution, the type of feed (D.C. or A.C.), the feed voltage and the type of equipment used for these circuits (control and verification of points, as well as semaphore and colour light signals) are so chosen as to prevent any traction current circulating in the circuit from being able to cause an untimely operation of the signalling equipment connected to the other end.

The measures taken by the different Administrations in order to obtain this result are examined below.

3.322. — It is obvious from the preceding discussion that circuits with earth return are generally proscribed on electrified lines. This does not mean that earth connections may not exist at some point of the circuits. On the *S.N.C.B.*, for example, although the above-mentioned circuits are insulated in principle, one terminal of the feed battery, in the case of a D.C. feed, may be connected to earth.

3.323. — From the above considerations, it is possible to draw the following conclusions.

A) *On D.C. electrified lines*, one may either:

1) systematically resort to the use of A.C. feeds for these circuits : in this case, equipment is used which is not liable to be actuated by the D.C., or transformers are connected between the line and the equipment; or one may :

2) use, for certain circuits, a D.C. supply, which must, however, have such a high voltage that, having regard to the maximum value of the potential which may occur in the most unfavourable cases between two points of the track at the place of the two ends of the circuit, there is no possibility of an untimely operation of the equipment.

The *S.N.C.B.* make use of both these solutions. The former is used for the control of signals, effected by means of single-element induction type line relays fed with A.C. of 50 c/s. The circuit of each relay is isolated in the relay room by means of a transformer with a 1 : 1 ratio so as to reduce the effect of the earth capacitance of the circuit feeding the relay.

The second solution, too, is used by the *S.N.C.B.* for circuits controlling and verifying the position of points (with voltages of 150 V and 40 V, respectively).

The *S.N.C.F.* make systematic use of solution 1) where no problems of sensitivity are encountered.

The *F.S.*, like the *S.N.C.B.*, use both solutions. In the second solution, the point control circuits are fed with a voltage of 144 V whilst the voltage of the verification circuits as well as that of any other D.C. signalling circuits outside the signal cabins is 48 V.

The voltage has been chosen after numerous tests so as to obtain a relay release voltage (minimum 24 V) well above the differences in potential which are due to the traction current and have been measured on the longest circuits in use.

B) *On A.C. electrified lines :*

in this case, it is possible to adopt solutions where the circuits are fed with D.C. and the signalling equipment is sufficiently indifferent to A.C. or, alternatively, where the circuits are fed with A.C. at certain specific frequencies which are generally well above the traction frequency and its more important harmonics, especially on lines of fairly great length.

In this matter, the *S.N.C.F.* distinguish between :

a) « local » circuits of 50 to 100 m length where it is assumed that the traction A.C. has no appreciable influence, and

b) line circuits of greater length where D.C. equipment with adequate indifference to A.C. of 50 c/s is used. In practice, this indifference is worked out on the basis of 75 V, 50 c/s per kilometre of double-track line, if buried cables without armouring are used.

Use is also made of circuits at special frequencies (audiofrequencies or pulsated frequencies), and the conditions of indifference to A.C. and its harmonics are studied individually in each case.

On the *F.S.*, the same principles have been adopted regarding the use of D.C., and of D.C. equipment. Feed conditions and equipment are so chosen that the alternating voltages liable to cause untimely operation of the equipment are very high

and well above the maximum value measured over a distance corresponding to the greatest length of the circuits concerned.

3.324. — The measures taken by the Administrations concerning signalling circuits other than track circuits ensure that there is no possibility of interference with these circuits either in normal operation or under abnormal conditions on the traction side.

This means, in principle, that the length of the circuits must be limited, as has been very clearly explained by the *S.N.C.F.* On A.C. electrified lines, this length is limited to 4 km to ensure the safety of the staff (maximum induced permanent voltage 120 V), if the ends of the circuit are accessible to the staff. On such lines, the equipment is of the D.C. type and, for normal operation (600 A in the catenary) the threshold of the insensitivity of the equipment to A.C. 50 c/s is fixed at 300 V.

In the event of abnormal conditions on the traction side (circuit breaker tripped) and where the induced voltage is liable to attain values in excess of 3 000 V for a time of less than 0.3 sec, the protection is deemed to be sufficiently ensured by imposing a time lag on the response of the equipment.

If it is necessary to use lines longer than 4 km, the safety of the personnel is ensured by means of isolating transformers protected against any contact with the primary (in buried boxes). In this case, however, the control circuits work with special types of A.C. (audio-frequency or pulsated frequency). Here, the high frequencies in the cable give rise to a problem of interference with the other circuits (signalling and telecommunication circuits), and the level used must therefore be lowered. This lowering of the level increases the sensitivity of disturbing induced alternating currents, and it becomes necessary to resort, as a protection, to solutions with modulation and coding.

3.325. — The measures taken by the Administrations, described above, preclude the possibility, in principle, of any one or several earth faults in the signalling cables being able to produce, in the signalling equipment connected to these circuits, any situations not compatible with safety.

As a general conclusion, it can be stated that a single earth fault will, in practice, always be harmless and that no dangerous situation is created by it. A periodic and systematic checking of the insulation of the cable conductors, both against each other and in relation to the sheath and armouring (if any), is a very useful precaution *(S.N.C.B.)*.

This precaution is also adopted by the *F.S.* where special earth indicators are used which provide an immediate indication of any such fault.

An analysis of the phenomena shows (*S.N.C.F.*) that the most unfavourable case of induction effects is encountered if one of the conductors at one of the ends of the line has an earth connection, and if the terminal equipment connected to it also has a point connected to earth. In that case, the equipment is exposed to the entire induced voltage. It is with this contingency in mind that the length limitations referred to above have been imposed.

This consideration gives rise to a question which is perhaps outside the scope of the present survey, viz., that of ensuring the proper working of the signalling equipment in the presence of several earth faults.

According to the *S.N.C.F.*, any untimely operation of the equipment can be adequately prevented by bi-polar sectioning of the line and eliminating all loop connection schemes (i.e. connections where the supply and the receiver equipment are at the same point and the switches at the opposite end of the line).

The same measures have been adopted by the *F.S.* who, in addition to the bi-polar sectioning of the line, provide a short-circuit connection of the line beyond the supply and the equipment at the opposite end, resulting in an increased safety margin in the case, which is the most frequent one, of installations on D.C. electrified lines.

3.33. — Telecommunication systems.

3.331. — It may be recalled that, in general, the telecommunication systems consist in most cases of :

— underground cable, overhead cable, or overhead line along D.C. electrified lines, or

— underground cable along A.C. electrified lines.

Certain Administrations, however, never use overhead circuits along any electrified lines, even with D.C. electrifications (*S.N.C.B.*).

It can be stated that the *F.S.* have now adopted the same practice and that they normally use, on their D.C. electrified system, underground cables and, occasionally, self-supporting overhead cables suspended from the supporting structures of the catenary system (though this solution is strictly confined to lines of secondary importance).

3.331.1. — As far as telephone circuits are concerned, it is useful to distinguish between :

A) Circuits connecting major exchanges;

B) Circuits of a special and omnibus type;

C) Subscriber circuits.

The relative importance of the three types mentioned above depends greatly on the structure of the telephone networks and on the operating conditions pertaining with the different Administrations.

Among the solutions indicated in the replies to the questionnaire, the following can be mentioned :

Ö.B.B. — Due to the use of translators on the circuits, induced impulse dialling or A.C. dialling is used for the telephone circuits.

D.B. — For short-distance subscriber lines, D.C. impulse dialling is used; there are no earth connections. For longer lines, induced impulse dialling is used. This dialling method is also used for local calls. For longer-distance calls, audio-frequency dialling is used exclusively (frequency 600 c/s). In the case of omnibus circuits with local battery, the call is initiated by means of magnetos. The equipment is isolated against the line by means of transformers.

S.N.C.B. — On the *S.N.C.B.* telephone system, calls are made either by means of D.C. impulses (for short-distance calls) or by means of inductive impulses transmitted to the line by the opening and closing of a transformer with its secondary connected to the circuit (this system being generally used if the distance exceeds 3 or 4 km, as it permits the use of translators). If the connection is worked with carrier currents, a signalling frequency of 3 850 c/s is used. The cable circuits are connected to the repeaters and terminal stations by means of translators so that a high degree of balance is ensured without difficulty.

C.F.F. — A distinction is made between :

a) *Omnibus lines with local battery :*

The telephone sets are connected to the line by means of a transformer or, in the case of lines of less than 10 km length, directly. Calls are made by means of a morse code with A.C. of 16 2/3 c/s or, if this supply fails, by 50 c/s current or magneto current (symmetric application in relation to earth);

b) *Subscriber lines :*

These lines have a central battery which is insulated against earth. Calls are made by means of A.C. of approx. 25 c/s, series-connected with the central battery; signalling and dialling with the D.C. supply of the central battery;

c) *Switchboard - to - switchboard junction lines :*

c 1) *Audio-frequency lines.* - The switchboard equipment is connected to the line across a transformer which serves to :

— provide a separation between the switchboard equipment and the line;

— match the impedances;

— establish symmetry in relation to earth;

— provide for signalling and dilling with 50 c/s currents or inductive impulses;

c 2) *Carrier current lines.* — The terminal installations and intermediate repeaters are separated from the line by means of transformers.

The distance between intermediate repeaters varies from 22 to 35 km. By their very nature, the call and dialling systems are not exposed to any influence of the traction currents.

S.N.C.F. — As far as telephone circuits are concerned, the *S.N.C.F.* distinguish between the following types :

A) *General network circuits,* which comprise :

a) *the long-distance circuits,* connecting the major exchanges with each other. These circuits are of the four-wire type and may consist :

— either of audio-frequency circuits (overhead physical circuits, loaded with 88/36 mH);

— or of a two-channel and three-channel system (one audio-frequency channel, one or two carrier frequency channels on circuits loaded with 22/9 mH);

— or, mostly, of a « 12 + 12 » carrier frequency system on non-loaded cabled circuits, or « six-channel », « 3 + 3 », 12 + 12 » on overhead lines.

Calls are made :

— at zero frequency (transmission of the virtual carrier of the channel concerned), with the « 12 + 12 » carrier frequency systems in cables, and some « 12 + 12 » carrier frequency systems on overhead lines;

— or at a frequency of 2 280 c/s, on the other cabled circuits;

— or at a frequency of 2 500 c/s on the « six-channel » and « 3 + 3 » systems on overhead lines;

— or at a frequency of 3 825 c/s on certain « 12 + 12 » systems on overhead lines.

If the circuits are for « automatic » operation, all switching operations are carried out on the four-wire lines. The circuits terminate exclusively in the two automatic switchboards at the ends.

If the circuits are for « manual » operation, each of them ends as a two-wire circuit. In that case, the calls of the six-channel systems are made at 50 c/s instead of 2 500 c/s;

b) *the medium and short distance circuits* connecting the major exchanges with the junctions or terminals. In principle, these circuits are of the two-wire audio-frequency type (loaded circuits 88/36 mH, non loaded circuits, overhead physical circuits).

Calls are made at 50 c/s.

If the circuits are for « automatic » operation, they are terminated and switched :

— as four-wire lines at the major exchanges;

— as two-wire lines at the junctions or terminals.

If the circuits are for « manual » operation, they are terminated as two-wire lines at both ends;

c) *selective omnibus circuits.*

These circuits are of the two-wire audio-frequency type (loaded circuits 88/36 mH or non-loaded circuits, overhead physical circuits).

Calls are made :

— exclusively at 50 c/s (Western or decimal code) on lines electrified for 25 kV, 50 c/s;

— either at 50 c/s (Western or decimal code) or with D.C. (Western code) on lines electrified for 1 500 V D.C.

B) *Special circuits.*

In this category, the circuits most frequently encountered are :

— the operating control circuits;

— the traction substation supervisory circuits;

— the traction alarm circuits.

The design of these circuits differs according to the type of line :

a) *1 500 V D.C. electrified lines with overhead telephone circuits (lines in the South-West):*

— operating control circuits: these are two-wire circuits. At one end of the circuit, the control post is listening in permanently. All the calls are centralized at the control post and initiated from there; they are made with D.C. alternated at 4 c/s (Western code). Although the same wires are used, calls and conversation can take place simultaneously;

— substation supervisory circuits;

— traction alarm circuits.

These are two-wire circuits leading from one substation to a point approximately half-way between two substations, and are thus comparatively short. At branch points, spaced at intervals of approximately 500 m, a portable local battery set can be connected. The substation, situated at the end of each circuit, is called up by magneto. If necessary, the substations can provide connections between the operating control circuit and the traction alarm circuit.

b) *1 500 V D.C. electrified lines with cabled underground telephone circuits:*

— operating control circuits;

— substation supervisory control circuits.

These are of the six-wire type and have the same composition (Plate II).

The calls are selective and unilateral, centralized at the control post. They are transmitted in D.C. alternated at 4 c/s (Western code) on the phantom of the distribution quad;

— traction alarm circuits.

These are likewise six-wire lines (Plate III).

They connect a control post with a group of secondary posts (four-wire type), consisting of water-tight sets along the track (with a spacing of approx. 750 m.

The secondary posts are fed from a central battery via the phantom of the distribution quad from a traction substation (in principle, from the station immediately ahead in the direction of the kilometre marking).

When the receiver at a secondary post is lifted, this is what happens:

— the substation feeding the post (substation ahead) is called;

— the control post is called by means of a 500 c/s current, transmitted from the substation during a period of 1 or 2 sec, over the microphone pair; this 500 c/s current is received at the control post by a tuned signal receiver;

c) *lines electrified with 25 kV, 50 c/s.*

1) *Old formula.*

Operating control circuits.

These are of the six-wire type (Plate IV).

The calls, selective and unilateral, are centralised, and are made with alternating capacitance discharges (Western code). The impulses obtained are similar to a non-sinusoidal alternating current of 4 c/s.

Substation supervisory circuits.

These are likewise of the six-wire type, but with one quad loaded 88 mH and a separate pair for the calls (Plate V).

As in the case of operating control circuits, the calls are made by alternating discharges of capacitances.

Traction alarm circuits.

These are six-wire circuits with transport pair (Plate VI).

The control post alone is called up. The lifting of the receiver at any of the secondary

posts short-circuits the phantom of the distribution quad thus causing, at one of the ends of the amplification section, the sensitive reception relay to drop.

This operation is transformed by a group of telephone relays into a transient transmission of 500 c/s current (for about 1 sec) to the control post where a tuned signal receiver operates the local call device.

2) *New formula.*

Operating control circuits.

Substation supervisory circuits.

These are of the four-wire type with single distribution quad (loaded 88 mH) (Plate VII).

The unilateral calls (in the direction from the control post to the secondary posts) are centralized at the control post and are selective (Western code). The impulses are transmitted over the line at 50 c/s and on the phantom of the quad. They are retranslated into alternated D.C. impulses in the call receiver systems of each of the secondary posts.

Traction alarm circuits.

These are likewise four-wire type circuits with a single distribution quad (loaded 88 mH) (Plate VIII).

The control post alone is called up; for safety reasons, however, the calls are duplicated.

First call :

At the end of the circuit, a 50 c/s supply feeds the phantom circuit of the quad. This 50 c/s current, regenerated at each repeater station, is received by a sensitive relay at the control post. The lifting of the receiver at any of the secondary posts causes the short-circuit of the phantom, the dropping of the relay, and the calling up of the control post. In the rest position of the circuit, the sensitive relay is permanently actuated, thus providing a certain indication that all the receivers at all secondary posts are duly replaced.

Second call :

When the receiver is lifted at one post and the man on the line has announced himself (« Here is the emergency telephone post at km... »), the call receiving system at the control post is actuated by a voice-responsive signal receiver at the end of the circuit.

F.S. — The *F.S.* make the following distinction :

A) *Long-distance telephony.*

The long-distance telephone system of the *F.S.* comprises three kinds of installations (Plate IX) :

— the so-called « local » networks, connecting all the sets of a given centre with each other through a central automatic railway telephone exchange;

— the so-called « regional » networks, connecting with each other all the centres within a region, and thus all the sets authorized to talk to each other over the automatic telephone system;

— the so-called « inter-regional » network which connects all the regional headquarters and the head office, and which can be used by all sets, irrespective of distance, authorized to talk to each other over the automatic telephone system.

With the automatic *F.S.* system, calls between authorized sets connected to different exchanges are made by means of prefix numbers which always consist of three digits.

The first digit indicates the type of network which must be used for the desired connection, thus :

— the number 8 indicates a call within the region in which the calling station is situated;

— the No. 9 indicates a call to a

station outside the region in which the calling station is situated (Plate X).

The signals switching the call in the desired direction are transmitted from one automatic exchange to another by means of A.C. impulses at audio-frequency between the different regional centres (No. 9 network), and by means of inductive impulses for connections within the same district (No. 8 network).

The audio-frequency signalling system uses the frequencies of 600 c/s, or 750 c/s, or a mixture of 600 and 750 c/s.

The *F.S.* have standardised the following values for the attenuation in their network (Plate XI) :

— 0 N for the circuits connecting the centres of the different districts;
— 1.5 N at the most, for the circuits connecting the regional centre with the sub-centres in the same region;
— 0.5 N at the most, for the circuits connecting with the individual sets.

Also, the « inter-regional » circuits between two different regions are operated as four-wire circuits, whilst the regional circuits for connections within the same region are operated as two-wire circuits.

B) *Short-distance telephony.*

The *F.S.* also have different trackside circuits, which can generally not be connected with each other; these circuits are used for the purposes of train operation, electric traction, substation supervision, etc.

In particular :

— circuit I is available for electric traction;
— circuit III is available for operating purposes;
— circuit V is used for the traction substations;
— circuit V*a* is used for level crossings, block posts, etc.;
— circuit D.C. is available to the station operating staff;
— circuit T.B. is available for the semi-automatic block system;
— circuits T.F.O. and T.F.S. are available for the control of train movements.

N.S. — On the *N.S.*, a distinction is made between the following types of circuits :

1) omnibus circuits between the lineside signals and the control posts.

   In the case of the older installations of this kind, these circuits are worked with local battery and with magneto calls. With the more modern installations, telephones with D.C. call system are used where the calls from the control post are made by a pole changer (frequency 25 c/s);

2) automatic telephone circuits with calls by means of A.C. impulses.

3.331.2. — Telegraphy.

Most of the Administrations have abandoned, or are about to abandon, the old Morse telegraphy system in favour of teleprinter communications wherever the telephone communication is not sufficient.

Generally, the short-distance connections are operated with D.C. whilst the longer and more important ones are operated by harmonic telegraphy at a carrier frequency as recommended by the C.C.I.T.T.

The aim is always to obtain the best possible balance of the equipments in relation to earth. Moreover, in the case of harmonic telegraphy, these sets are connected by cables equipped with translators so as to protect the systems sufficiently against the effects of the electric traction currents.

The layout of the telegraphic networks is obviously governed, to a great extent, by the very structure of the railway systems of the different countries, and by operating requirements.

In general, a star-shaped layout is favoured, with teleprinters connected to satellite telegraphic exchanges which are, in their turn, connected to the main telegraphic exchanges.

With such a layout, three types of circuits can, in general, be encountered :

— circuit connecting the main exchanges with each other;
— circuits connecting the satellite exchanges with the main exchanges;
— circuits connecting the individual teleprinters with the satellite exchanges.

The replies received can be set out as follows :

Ö.B.B. — A.C. or medium-frequency telegraphy systems are in use.

D.B. — Short-distance connections are operated by D.C., long-distance connections by means of audio-frequencies.

S.N.C.B. — Connections between distant individual stations and the central automatic exchange at Brussels are operated by means of harmonic telegraphy systems. Connections between nearer individual stations and the Brussels exchange are operated with D.C.

R.E.N.F.E. — The use of teleprinter communications is envisaged in the near future.

C.F.F. — The teleprinter system works with D.C. two-circuit transmission on three-wire lines up to 200 km. The battery for the transmission of the impulses has no earth connection.

S.N.C.F. — A distinction must be made between :

A) *Circuits connecting the main automatic exchanges.*

These circuits consist exclusively of harmonic telegraphy channels of the four-wire type, the transmissions in both directions being independent.

In accordance with the C.C.I.T.T. recommendations, the carrier frequencies are staggered by 120 c/s from 420 c/s (7th harmonic of 60 c/s) to 3 180 c/s. The telegraphic channels are transmitted on the cables either on metallic circuits, loaded or otherwise, or on carrier frequency telephone channels (high-frequency channels of the 22/9 mH circuits, or high-frequency channels of the « 12 + 12 » systems on non-loaded channels).

B) *Circuits connecting the main exchanges with the satellite exchanges.*

Where the satellite exchanges are some distance away from the main exchanges, the system is the same as that described under A) above.

Where the satellite exchanges are in the vicinity of the main exchanges, circuit problems do not arise because the apparatus is, in practice, installed in the same room and connections are made by D.C. through cable connections between their respective installations.

C) *Circuits connecting the terminal posts.*

1) Stations some distance away :

a) stations at isolated points are connected by means of bi-vocal systems with frequency modulation. With this arrangement, it is possible to set up a telegraphic duplex circuit on a two-wire circuit already used for telephony. A frequency band ranging from about 1 500 to about 2 000 c/s is set aside within the telephone frequency band by means of band pass filters in order to serve for the transmission of telegraphic modulation signals;

b) if two or more stations are close together, they may be connected to their satellite exchange by harmonic telegraphy channels identical with those already described, provided that the necessary circuits are available. If this it not the case, these stations are connected through bi-vocal systems in the same way as isolated stations;

2) Stations near-by :

With distances not exceeding a few kilometres, the connection is made by D.C., using *four-wires* (two pairs or one quad), as an earth return of the telegraphic modulation currents is not permitted in the proximity of electrified tracks.

N.S. — The *N.S.* distinguish between the following types of circuits :

1) direct connections between two teleprinters (especially for the seat reservation system of the Trans-Europe Trains);
2) connections through a central exchange;
3) harmonic telegraphy circuits;
4) D.C. telegraphy circuits.

3.332. — In principle, earth connections are avoided on all telecommunication circuits.

In certain cases, one pole of the central battery of the telephone exchanges is earthed : *S.N.C.B.; Lower Congo-Katanga; C.F.F.* (with special precautions as regards the dielectric strength of the circuit and the terminal set, which must be at least 2 000 V for the cables and 1 500 V for the terminal sets); *P.K.P.* (the subscriber circuits, sometimes connected by long-distance cable, have a galvanic earth connection across the windings of the feed relay at the exchange).

3.333. — The following data have been reported :

D.B. — The sensitivity coefficient of the lines varies between 0.001 and 0.002.

The degree of asymmetry of the sets at 800 c/s is better than 0.03. With connections across translators, this lack of balance can be ignored.

S.N.C.B. — The sensitivity coefficient for cabled circuits, measured between the ends of the circuits, is lower than 0.001.

Many Administrations have carried out electric measurements in this respect though precise details are not yet available; other Administrations propose to carry out tests for this purpose.

3.334. — The following details concerning the admissible noise voltages have come to hand :

D.B. :

Telephone lines for public or international service : 2 mV ... 1 mV.

Telephone lines not used for public service :

a) cabled circuits : 5 mV ... 1 mV;

b) overhead line or overhead cable : 10 mV ... 5 mV.

S.N.C.B. — Under normal conditions, the permitted noise limit value is 0.002. No specifications have been made from a danger point of view. Some interesting results of induction tests of telephone circuits carried out in 1952 are shown in the Appendix.

S.N.C.F. — As regards the danger voltages to which the telecommunication circuits are exposed, it is convenient to distinguish between :

A) local distribution cables, i.e. cables of relatively short length where the circuits, protected by fuses and overvoltage protection, are connected to the terminal sets without inserting terminal translators.

With this type of circuit, the limit values for the induced longitudinal e.m.f. have been fixed at :

60 V under normal working conditions;

430 V under short-circuit conditions;

B) long-distance cables where the circuits terminate in translators (without the insertion of lightning arresters between conductors and earth), where it is considered that the induced longitudinal e.m.f. should not exceed a value equal to 60 % of the lowest of the breakdown voltages of the cable and of the different parts of the installations; in the case of the *S.N.C.F.*, this corresponds to :

$$\frac{60}{100} \times 2\,000 = 1\,200 \text{ V.}$$

Along the lines electrified for 25 kV, 50 c/s, the limitation of the induced e.m.f. to the maximum permissible value is obtained by the insertion of 1 : 1 isolating translators (cf. reply to 2.231.1) where the dielectric strength between the windings, and between each winding and mass, is at least 2 000 V.

If it is necessary to carry out work on these cables without the possibility of disconnecting the traction current, special measures must be taken to protect the staff (cf. reply to 3.12).

As regards the harmful effects to which the telecommunication circuits are exposed, the limit of the psophometric e.m.f. is now set at 2 mV.

It is also specified that the psophometric power due to line noises (related to the point of relative zero level) must not exceed during more than 1 % of the time the limit value of 3 picoW per kilometre of circuit (not including the terminal installations).

Other Administrations state that the noise level values permitted by them correspond to those laid down in the C.C.I.T.T. directives.

APPENDIX.

Induction tests carried out by the S.N.C.B.

The induction tests in telephone circuits during short circuits on D.C. catenary lines were carried out in November 1952 and included the following contingencies:

case *a*: 2 catenaries in parallel, and return through rail;

case *b*: 1 catenary, and return through the rail;

case *c*: 1 forward and return through the catenary;

case *d*: 1 catenary and return through the rail, longer circuit than in case *b*.

The first three tests have been carried out on the Charleroi-Luttre line, and the fourth on the Charleroi-Baulers line.

The curves showing the rise and fall of the short-circuit current were obtained by means of a Siemens Dudell type oscillograph. The same device as well as a cathodic oscillograph served to measure the voltage between one wire of the telephone cable, and the lead sheath. In order to avoid any error due to the Siemens oscillograph, use was made of a highly sensitive element, and the total circuit resistance was about 140 000 ohm.

By means of a cathodic oscillograph, the attempt was made to measure the voltage between the wires of the same circuit; it was, however, found at once that no such measurements were possible. The telephone receiver was therefore used, but it was not possible to detect the slightest « crack » at the moment of the short-circuit.

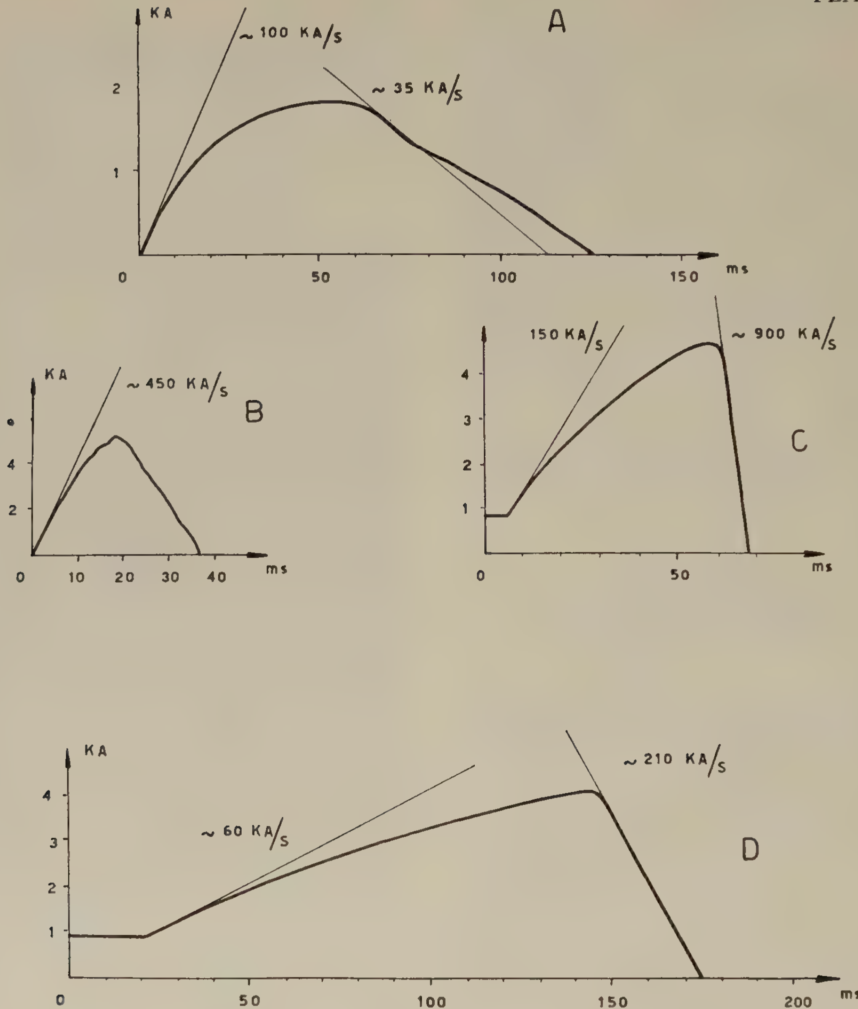
Test	I_{DC} *max. Amps.*	*di/dt max. Amp/sec.*	*Length of circuit km*	*E wire/lead sheath max. voltage*		*E wire/lead shealth Volt/km Amp/msec.*
				on-loaded circuit	*129 mH circuit*	
a	4 400	285×10^3	15.250	540	—	0.124
b	3 000	156×10^3	15.250	340	—	0.143
c	The oscillograph did not provide any useful indication		15.250	0	—	0
d	1 500	115×10^3	28.050	390	510	0.121

N. B. — The *di/dt* value reaches its maximum during the setting up of the short-circuit, and not during the interruption.

Conclusions.

1. In the case of non-loaded circuits, the induced voltage between wires and lead was of the order of 0.12 V/km/A/millisec.
   For heavily loaded circuits, 129 mH every 1 300 m, the value was 30 % higher (one single test).
2. The voltage measured between wires and lead (longitudinal voltage) is clearly lower than the voltage which the cable can withstand without suffering damage.
3. The induced voltage between the wires of the same pair during a short-circuit was not perceptible to the ear.

PLATE I.



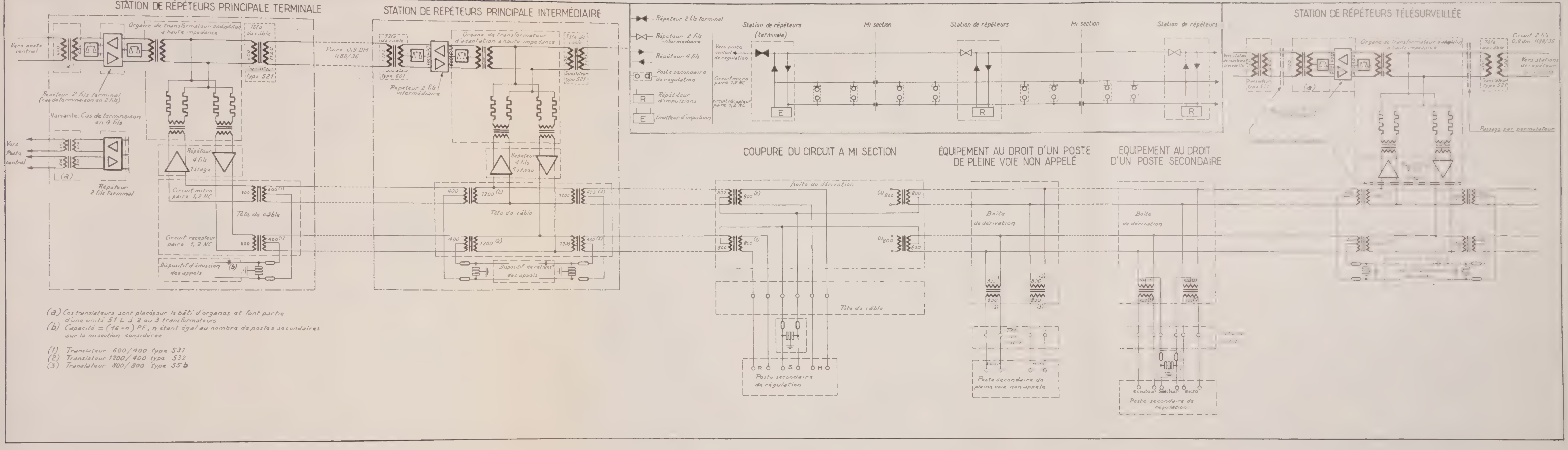
Short-circuit tests of the Italian State Railways on a 3 000 V D.C. electrified line.

Oscillogram A : Example of disconnection by means of a type of circuit breaker which generally results in a rate of decrease less steep than the initial rate of rise.

Oscillogram B : Example of disconnection by means of a type of circuit breaker which generally results in a rate of decrease of the same order of magnitude as the initial rate of rise.

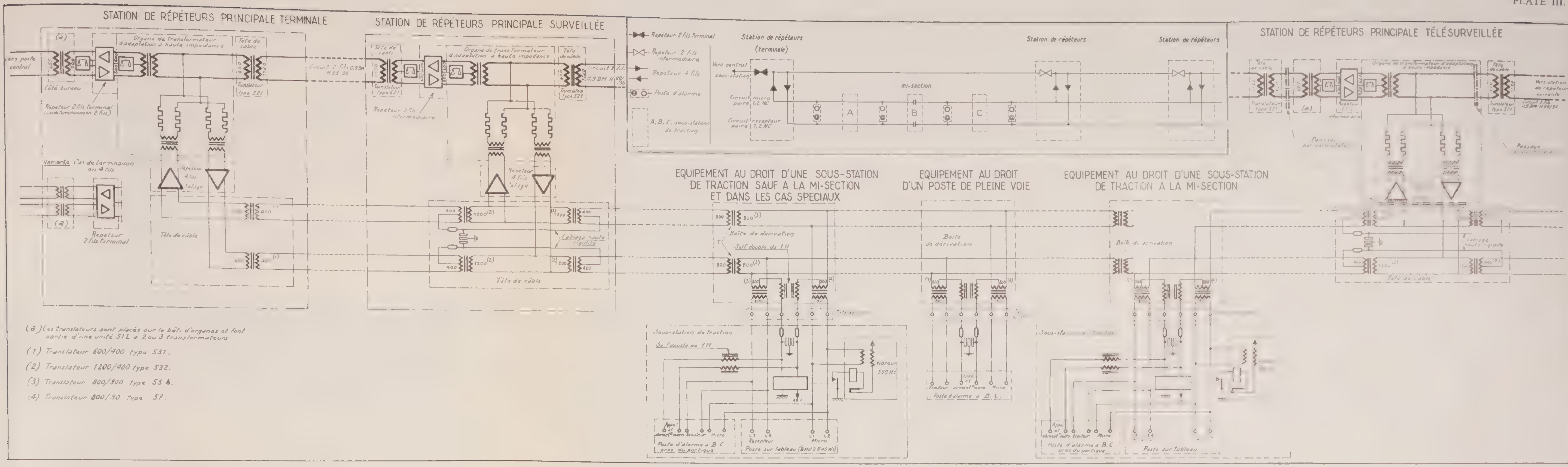
Oscillograms C and D : Examples of disconnections by means of a type of circuit breaker which generally results in a rate of decrease steeper than the initial rate of rise.

Note : The circuit conditions (resistance and inductance) are different in each of the cases A, B, C and D.



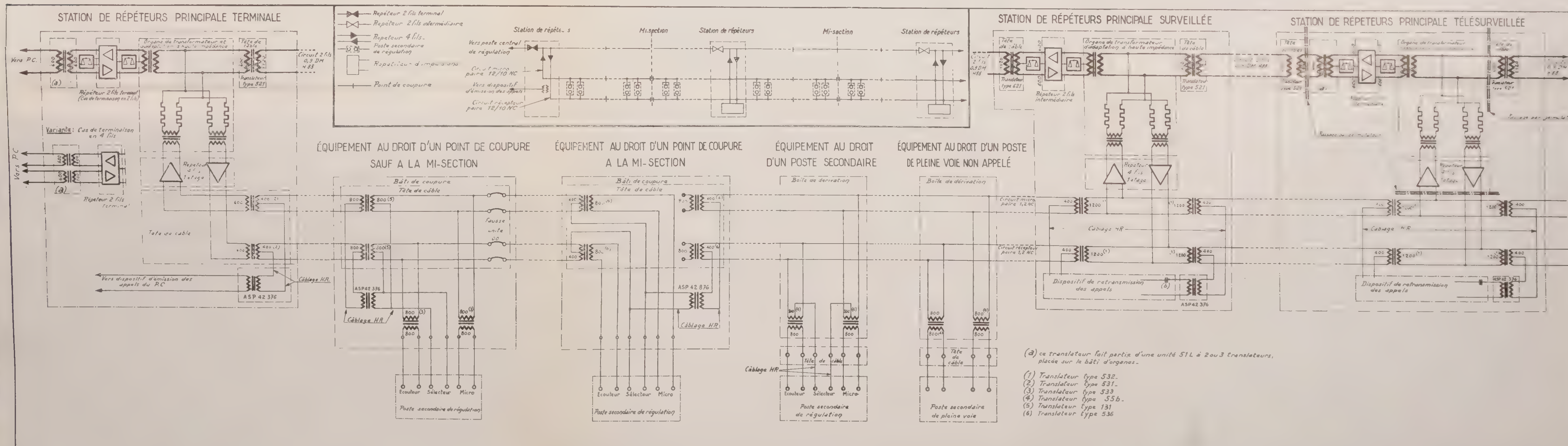
Explanation of the French wording :

a) Ces translateurs sont placés sur le bâti d'organe et font partie d'une unité 51 L à 2 ou 3 transformateurs = *a*) these transformers are mounted on the rack and form part of a 51 L unit consisting of 2 or 3 transformers. — *b*) Capacité = (16 + *n*) P F, *n* étant égal au nombre des postes secondaires sur la mi-section considérée = *b*) capacitance = (16 + *n*) P F, where *n* is the number of secondary parts of the half-section concerned. — Boîte de dérivation = junction box. — Circuit micro-paire 1.2 N C = micro circuit pair 1.2 mm unloaded. — Circuit récapteur = receiver circuit. — Coupure du circuit à mi-section = mid-point circuit breakers. — Dispositif d'émission des appels = call transmitter device. — Dispositif de retransmission des appels = call re-transmitter device. — Ecouteur = receiver. — Emetteur d'impulsion = impulse transmitter. — Equipement au droit d'un poste de pleine voie non appelé = equipment of non-callable lineside post. — Equipement au droit d'un poste secondaire = equipment of secondary post. — Mi-section = section mid-point. — Organe de transformateur d'adaptation à haute impédance = high impedance matching transformer organ. — Passage par permutateur = passage via distribution frame. — Poste secondaire de régulation = secondary regulating post. — Poste secondaire de pleine voie non appelé = non callable lineside post. — Répéteur 2 fils terminal = 2-wire terminal amplifier. — Répéteur 2 fils intermédiaire = 2-wire intermediate amplifier. — Répéteur 4 fils 1 étage = 4-wire 1-stage amplifier. — Répéteur 2 fils terminal = 2-wire terminal amplifier. — R : répéteur d'impulsions = R : impulse repeater. — Station de répéteurs principale terminale = main terminal amplifier station. — Station de répéteurs principale intermédiaire = main intermediate amplifier station. — Station de répéteurs télésurveillée = remote controlled amplifier station. — Station de répéteurs = amplifier station. — Sélecteur = selector. — Tête de cable = cable head. — Translateur type 521 = transformer. — Variante : cas de terminaison en 4 fils = alternative 4 wire termination. — Vers poste central = to exchange. — Vers station de répéteurs précédente = to preceding repeater station. — Vers poste central de régulation = to central control-post.



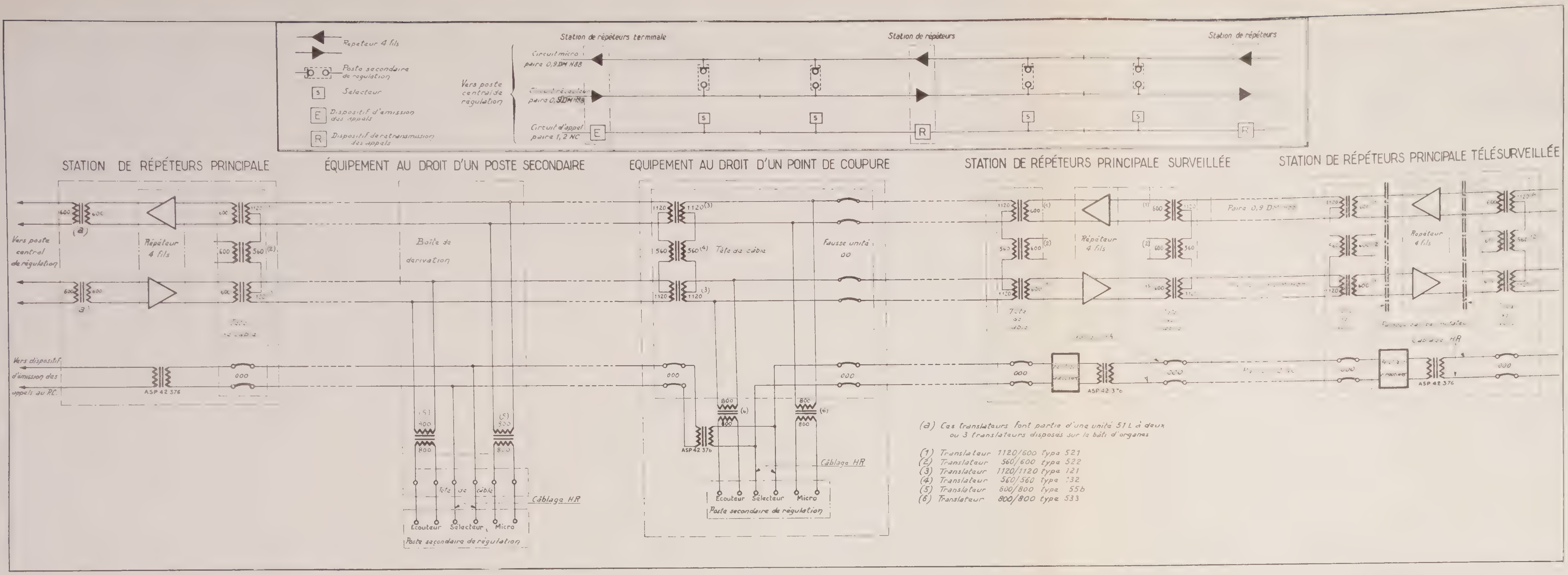
Explanation of the French wording :

a) Ces translateurs sont placés sur le bâti d'organes et font partie d'une unité 51 L à 2 ou 3 transformateurs = a) these transformers are mounted on the rack and form parts of a 51 L unit consisting of 2 or 3 transformers. — A, B, C sous-stations de traction = A, B, C traction substations. — Appel et alimentation, micro, écouteur = call and micro feed, receiver. — Boîte de dérivation Sald double de 1 H = junction box, 1 H double choke. — Câblage haute rigidité = high rigidity voltage cabling. — Circuit récepteur, paire 1.2 N C = receiver circuit, pair 1.2 mm dia. unloaded. — Circuit micro, paire 1.2 N C = micro circuit, pair 1.2 mm dia. — Côté bureau = exchange side. — Equipement au droit d'une sous-station de traction, sauf à la mi-section et dans les cas spéciaux = equipment at traction substation other than at section mid-point or in special cases. — Equipement au droit d'un poste de pleine voie = equipment at lineside post. — Equipement au droit d'une sous-station de traction à la mi-section = equipment at traction substation at section mid-point. — Mi-section = section mid-point. — Organe de transformateur d'adaptation à haute impédance = high impedance matching transformer organ. — Passage par permutateur = passage via distribution frame. — Poste d'alarme = alarm post. — Poste d'alarme à B.C. près du portique = central battery type alarm post near gantry. — Récepteur, micro poste sur tableau (B M U 2 4 S W 1) = receiver-control board mounted set. — Répéteur 2 fils terminal (cas de terminaison en 2 fils) = 2-wire terminal amplifier with 2-wire termination. — Répéteur 2 fils terminal = 2-wire terminal amplifier. — Répéteur 2 fils intermédiaire = 2-wire intermediate amplifier. — Répéteur 4 fils 1 étage = 4-wire 1-stage amplifier. — Sous-station de traction self double de 1 H = traction substation, 1 H double choke. — Station de répéteurs principale terminale = main terminal amplifier station. — Station de répéteurs principale surveillée = main manned amplifier station. — Station de répéteurs principale télésurveillée = main remote-controlled amplifier station. — Station de [illegible] = terminal station amplifier. — Tête de câble = cable head. — Tra[illegible] = transformer, type 521. — Variante : cas de terminaison en 4 fils [illegible] 4-wire termination. — Vers poste central = to exchange. — Vers station [illegible] suivante = to the following amplifier station. — Vibreur 500 Hz = 500 c/s vibrator.



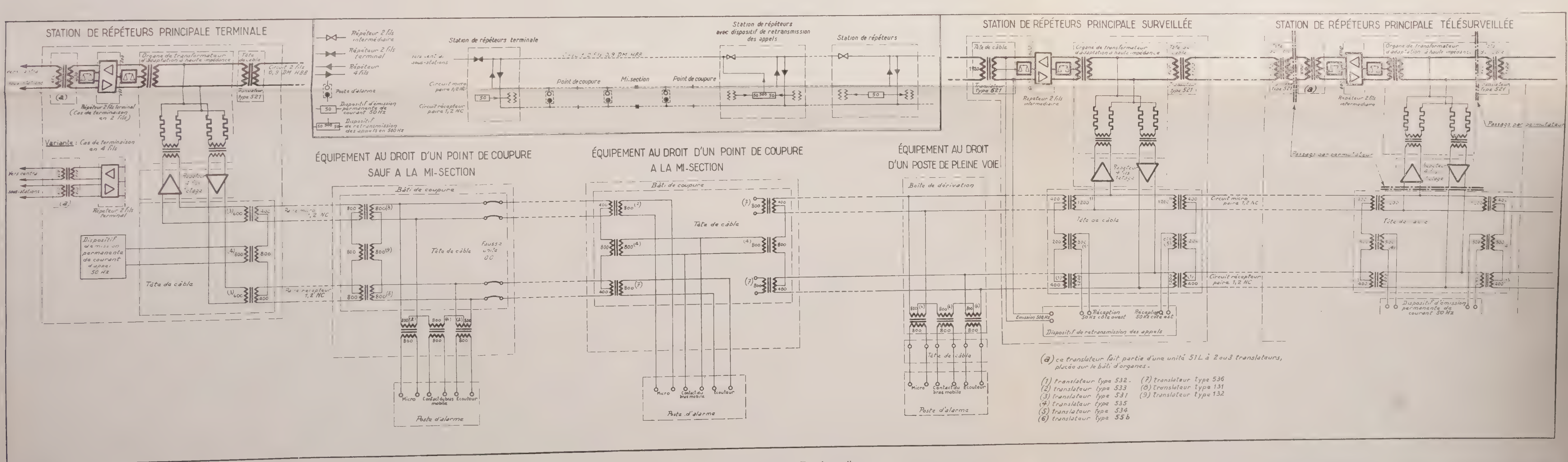
Explanation of the French wording :

a) Ce translateur fait partie d'une unité 51 L à 2 ou 3 translateurs placée sur le bâti d'organes = a) this transformer forms part of a 51 L unit consisting of 2 or 3 transformers mounted on the rack. — Boîte de dérivation = junction box. — Câblage H R = high breakdown voltage cabling. — Circuit micro = micro circuit. — Circuit récepteur = receiver circuit. — Dispositif de retransmission des appels = call re-transmission device. — Ecouteur = receiver. — Equipement au droit point de coupure sauf à la mi-section = equipment at sectioning point other than section mid-point. — Equipement au droit d'un point de coupure à la mi-section = equipment at sectioning point at section mid-point. — Equipement au droit d'un poste secondaire = equipment at secondary post. — Equipement au droit d'un poste de pleine voie non appelé = equipment at non-callable lineside post. — Fausse unité = dummy unit. — Mi-section = section mid-point. — Organe de transformateur et d'adaptation à haute impédance = high impedance matching transformer organ. — Passage par permutateur = passage via distribution frame. — Point de coupure = sectioning point. — Poste secondaire de régulation = secondary regulating post. — Poste secondaire de pleine voie = lineside secondary post. — Répéteur 2 fils terminal = 2-wire terminal amplifier. — Répéteur 2 fils intermédiaire = 2-wire intermediate amplifier. — Répéteur 4 fils 1 étage = 4-wire 1-stage amplifier. — Répéteur 2 fils terminal (cas de terminaison en 2 fils) = amplifier with 2-wire termination. — Répétiteur d'impulsions = impulse repeater. — Sélecteur = selector. — Station de répéteurs principale terminale = main terminal amplifier station. — Station de répéteurs principale surveillée = main manned amplifier station. — Station de répéteurs principale télésurveillée = main remote-controlled amplifier station. — Station de répéteurs = amplifier station. — Tête de câble = cable head. — Translateur = transformer. — Variante : cas de terminaison en 4 fils = alternative : 4-wire termination. — Vers poste central de régulation = to central control post. — Vers dispositif d'émission des appels = to call transmitter. — Vers dispositif d'émission des appels du P.C. = to call transmitter at central post. — Vers P.C. = to control post.



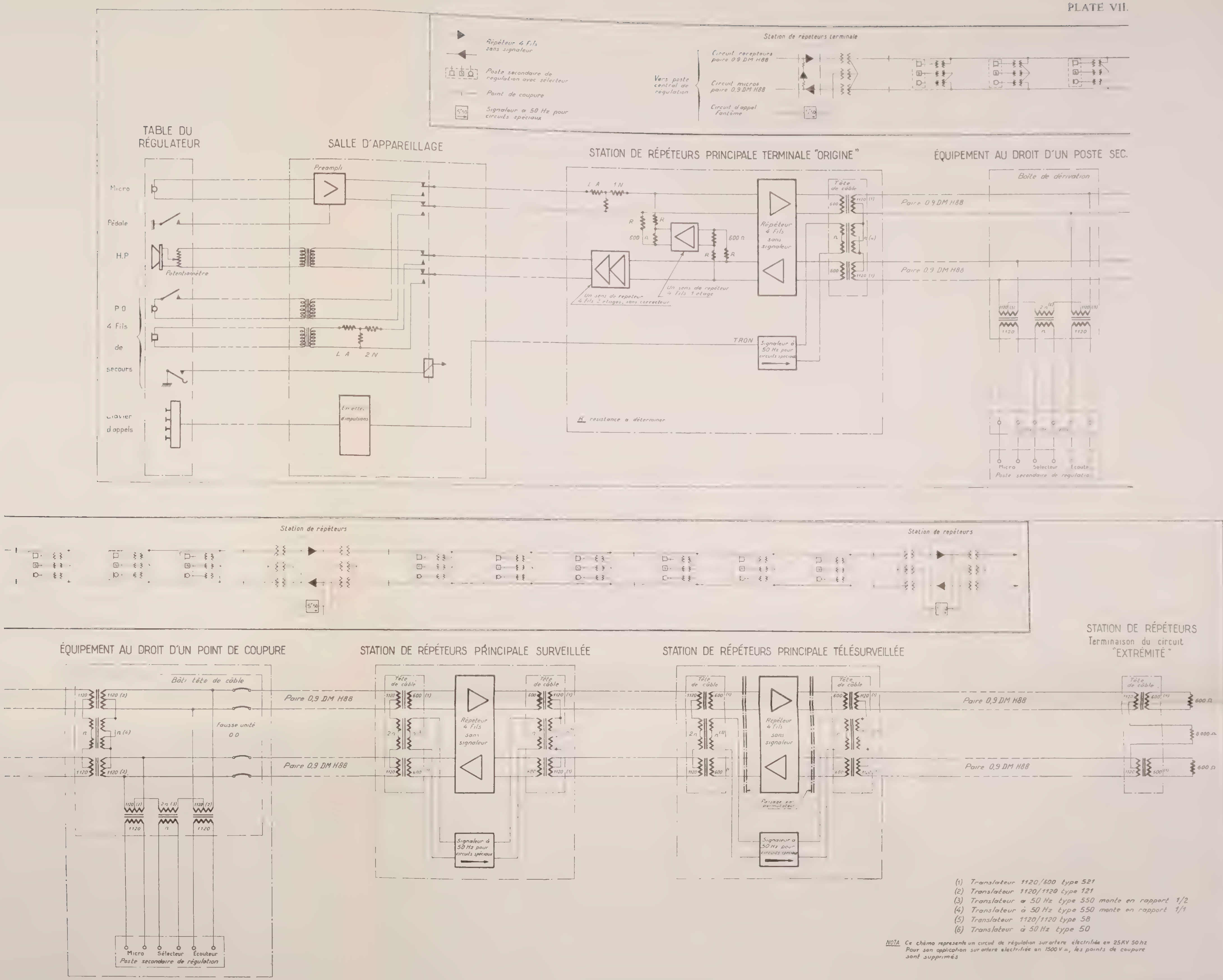
Explanation of the French wording :

a) Ces translateurs font partie d'une unité 51 L à 2 ou 3 translateurs disposés sur le bâti d'organes = these transformers form parts of 51 L unit of 2 or 3 transformers mounted on the rack. — Boîte de dérivation = junction box. — Câblage H R = high breakdown voltage cabling. — Circuit micro = micro circuit. — Circuit récepteur = receiver circuit. — Circuit d'appel = call circuit. — Dispositif d'émission = call transmitter. — Dispositif de retransmission des appels = call re-transmitter. — Ecouteur = receiver. — Equipement au droit d'un poste secondaire = equipment at secondary post. — Equipement au droit d'un point de coupure = equipment at sectioning point. — Paire, 1.2 N C = pair 1.2 mm dia. unloaded. — Poste secondaire de régulation = secondary regulating post. — Récepteur 4 fils = 4-wire amplifier. — Répétiteur d'impulsions = impulse repeater. — Sélecteur = selector. — Station de répéteurs principale = main amplifier station. — Station de répéteurs principale surveillée = main manned amplifier station. — Station de répéteurs principale télésurveillée = main remote-controlled amplifier station. — Station de répéteurs terminale = terminal amplifier station. — Station de répéteurs = amplifier station. — Tête de câble = cable head. — Translateur = transformer. — Vers poste central de régulation = to central control post. — Vers dispositif d'émission des appels au P.C. = to call transmitter at control post



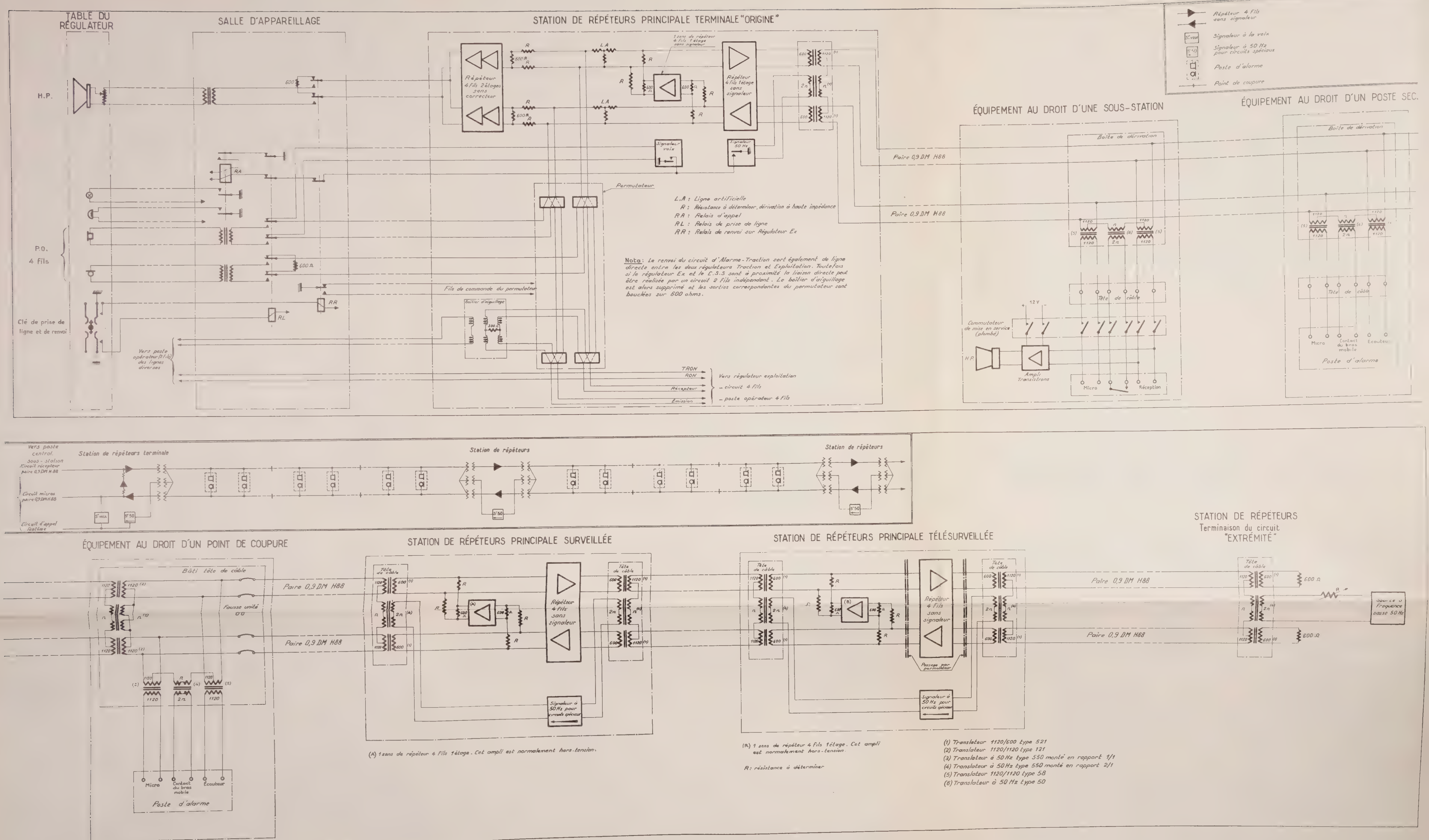
Explanation of the French wording :

a) Ce translateur fait partie d'une unité 51 L à 2 ou 3 translateurs placée sur le bâti d'organe = *a*) this transformer forms part of a 51 L unit consisting of 2 or 3 transformers mounted on the rack. — Contact du bras écouteur mobile = movable arm contact. — Dispositif d'émission permanente de courant 50 Hz = device for permanent transmission at 50 c/s call current. — Dispositif de retransmission des appels en 500 Hz = device for retransmission of calls at 500 c/s. — Dispositif de retransmission des appels = call retransmission device. — Fausse unité = dummy unit. — Emission 500 Hz = 500 c/s transmission. — Equipement au droit d'un point de coupure, sauf à la mi-section = equipment at sectioning point other than section mid-point. — Equipement au droit d'un point de coupure à la mi-section = equipment at sectioning point at section mid-point. — Equipement au droit d'un poste de pleine voie = equipment at lineside post. — Organe de transformateur d'adaptation à haute impédance = high impedance matching transformer organ. — Paire micro = micro pair. — Paire récepteur, 1.2 N C = receiver pair, 1.2 mm. — Passage par permutateur = passage via distribution frame. — Poste d'alarme = alarm post. — Réception 50 Hz côté est = 50 c.s. reception east side. — Réception 50 Hz côté ouest = 50 c.s. reception west side. — Répéteur 2 fils intermédiaire = 2-wire intermediate amplifier. — Répéteur 2 fils terminal = 2-wire terminal amplifier. — Répéteur 2 fils terminal (cas de terminaison en 2 fils) = 2-wire terminal (with 2-wire termination). — Répéteur 4 fils 1 étage = 4-wire 1-stage amplifier. — Station de répéteurs principale terminale = main terminal amplifier station. — Station de répéteurs principale surveillée = main manned amplifier station. — Station de répéteurs principale télésurveillée = main remote-controlled amplifier station. — Station de répéteurs terminale = terminal amplifier station. — Station de répéteurs avec dispositif de retransmission des appels = amplifier station with call retransmission device. — Station de répéteurs = amplifier station. — Tête de câble = cable head. — Translateur = transformer. — Variante : cas de terminaison en 4 fils = alternative : 4-wire termination. — Vers central sous-station = to substation switchboard.



Explanation of the French wording :

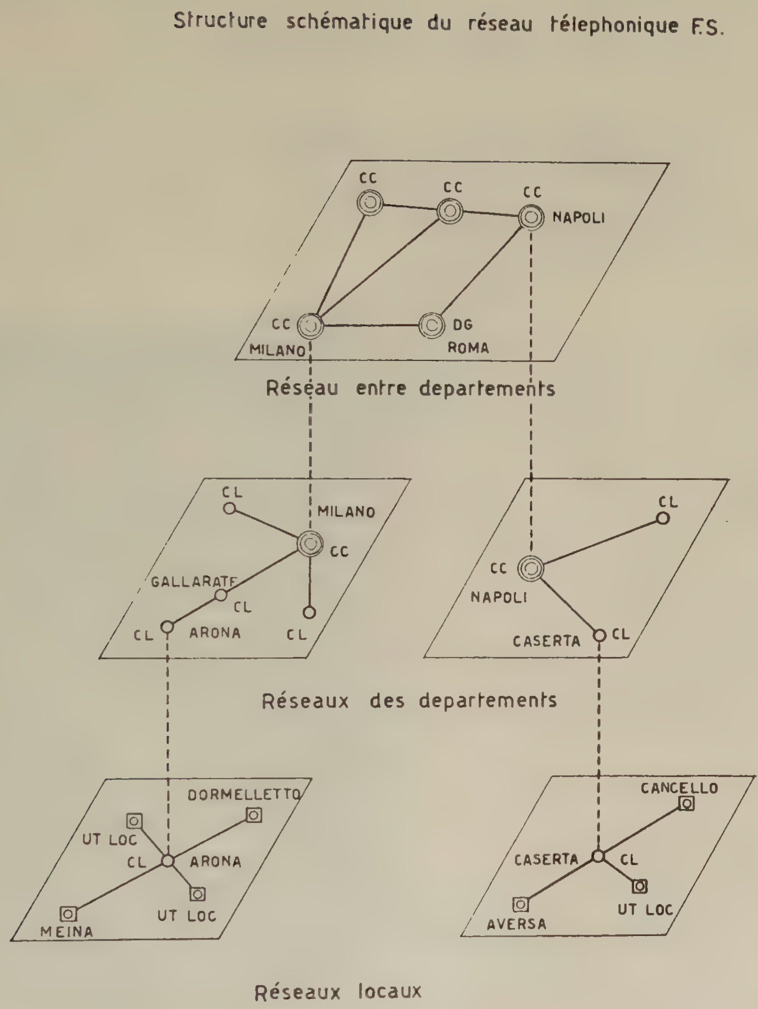
Bâti tête de câble = cable head frame. — Boîte de dérivation = junction box. — Circuit récepteur = receiver circuit. — Circuit micro = micro circuit. — Circuit d'appel fantôme = phantom call. — Clavier d'appels = call keyboard. — Equipement au droit d'un poste secondaire = equipment at secondary point. — Equipement au droit d'un point de coupure = equipment at sectioning point. — Fausse unité = dummy unit. — H.P. = loudspeaker. — *Nota :* ce schéma représente un circuit de régulation sur artère électrifiée en 25 kV, 50 Hz; pour son application sur artère électrifiée en 1 500 V les points de coupure sont supprimés = *Note :* this diagram shows a control on a 25 kV, 50 c/s electrified line; on 1 500 V D.C. lines, the sectioning points are omitted. — Passage par permutateur = passage via distribution frame. — Pédale = foot switch. — Point de coupure = sectioning point. — P.O. 4 fils de secours = standard 4-wire stand-by instrument. — Poste secondaire de régulation avec sélecteur = secondary regulating post with selector. — Poste secondaire de régulation micro-sélecteur-écouteur = secondary regulating post receiver-selector-microphone. — Potentiomètre = potentiometer. — Répéteur 4 fils sans signaleur = 4-wire amplifier without signalling device. — Résistance à déterminer = resistance to be determined. — Salle d'appareillage = equipment room. — Signaleur à 50 Hz pour circuits spéciaux = 50 c/s signalling device for special circuits. — Station de répéteurs terminale « origine » = main « origin » terminal amplifier station. — Station de répéteurs principale surveillée = main manned amplifier station. — Station de répéteurs principale télésurveillée = main remote-controlled amplifier station. — Station de répéteurs de circuit (extrémité) = terminal amplifier station (end of circuit). — Station de répéteurs terminale = terminal amplifier station. — Table du régulateur = control desk. — Tête de câble = cable head. — Translateur = transformer. — Un sens de répéteur 4 fils 2 étages sans correcteur = one-way 4-wire 2-stage amplifier without corrector. — Un sens de répéteur 4 fils 1 étage = one-way 4-wire 1-stage amplifier. — Vers poste central de régulation = to central control post.



Explanation of the French wording :

a) Un sens de répéteur 4 fils 1 étage; cet ampli est normalement hors tension = *a*) one-way 1-stage 4-wire amplifier; this amplifier is normally dead. — Bâti tête de câble = cable head frame. — Circuit 4 fils = 4-wire circuit. — Circuit micro = micro circuit. — Circuit d'appel fantôme = phantom call circuit. — Clé de prise de ligne et de renvoi = key for connection to, and transfer of line. — Equipement au droit d'une sous-station = equipment at substation. — Equipement au droit d'un poste secondaire = equipment at secondary post. — Equipement au droit d'un point de coupure = equipment at sectioning point. — Fils de commande du permutateur, boîtier d'aiguillage = permutator control wires, conversion box. — H.P. = loudspeaker. — Ligne artificielle = artificial line. — *Nota :* le renvoi du circuit d'alarme-traction sert également de ligne directe entre les deux régulateurs traction et exploitation; toutefois, si le régulateur Ex et le C.S.S. sont à proximité, la liaison directe peut être réalisée par un circuit 2 fils indépendant; le boîtier d'aiguillage est alors supprimé et les sorties correspondantes du permutateur sont bouclées sur 600 ohms = *Note :* the transfer line of the traction alarm circuit serves also as a direct line between traction and operating controller; but if the 2 controllers are close to each other, the connection may take the form of an independent 2-wire circuit; the conversion box is then omitted and the corresponding outputs of the switch device are looped over 600 ohms. — Passage par permutateur = passage via distribution frame. — Permutateur = permutator. — Poste d'alarme = alarm post. — Poste opérateur 4 fils = 4-wire operating set. — Poste d'alarme, micro-contact du bras mobile-écouteur = alarm post, micro-movable arm contact-receiver. — Point de coupure = sectioning point. — P.O. 4 fils = standard 4-wire instrument. — Résistance à déterminer, dérivation à haute impédance = resistance to be determined, high impedance shunt. — Relais de prise de ligne = line connection relay. — Relais d'appels = call relay. — Relais de renvoi sur régulateur = return relay to operating controller. — Répéteur 4 fils sans signaleur = 4-wire amplifier without signalling device. — Répéteur 4 fils 2 étages sans correcteur = 4-wire 2-stage amplifier without corrector. — Répéteur 4 fils 1 étage sans signaleur = 4-wire 1-stage amplifier without signalling device. — Répéteur 4 fils sans signaleur = 4-way amplifier without signalling device. — Résistance à déterminer = resistance to be determined. — Salle d'appareillage = equipment room. — Signaleur à la voix = voice signalling. — Signaleur à 50 Hz pour circuits spéciaux = 50 c/s signalling device for special circuits. — Signaleur voix = voice signalling device. — Signaleur 50 Hz = 50 c/s signalling device. — Station de répéteurs principale terminale (origine) = main « origin » terminal amplifier station. — Source à fréquence basse 50 Hz = low frequency (50 c/s) supply. — Station de répéteurs principale surveillée = main manned amplifier station. — Station de répéteurs principale télésurveillée = main remote-controlled amplifier station. — Station de répéteurs terminaison du circuit « extremité » = terminal amplifier station « end of circuit ». — Station de répéteurs terminale = terminal amplifier station. — Table du régulateur = control desk. — Translateur = transformer. — Un sens de répéteurs 4 fils 1 étage sans signaleur = one-way 4-wire 1-stage amplifier without signalling device. — Vers régulateur exploitation = to operating controller. — Vers poste central, circuit récepteur = to substation control post, receiver circuit. — Vers poste opérateur (2 fils) des lignes diverses = to operating post (2-wire) of the different lines.

PLATE IX.



Structure schématique du réseau téléphonique F.S. = Schematic layout of the FS telephone network.

Réseau entre départements = Inter-regional network.

Réseaux des départements = Regional networks.

Réseaux locaux = Local networks.

PLATE X.

FS telephone network with teleselection.

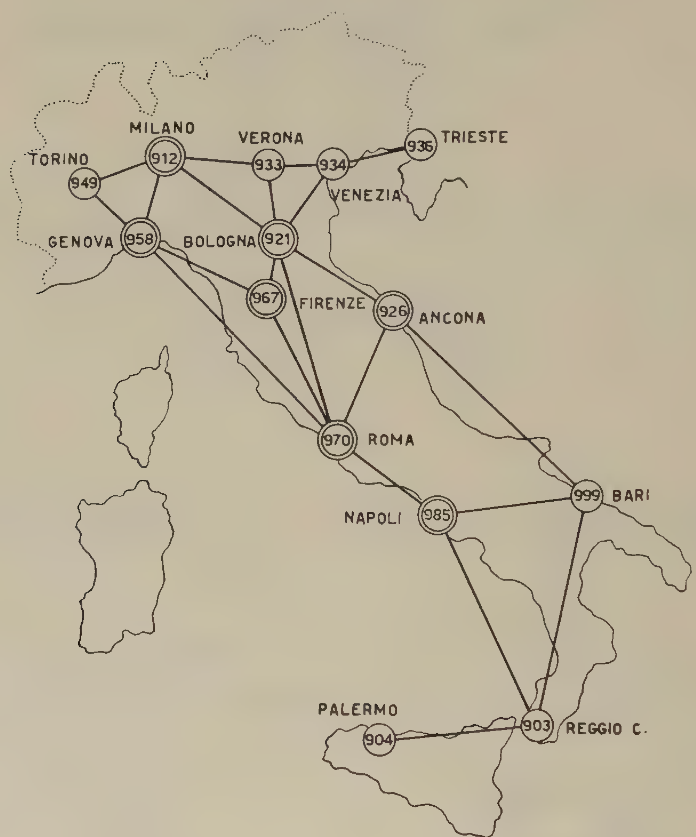
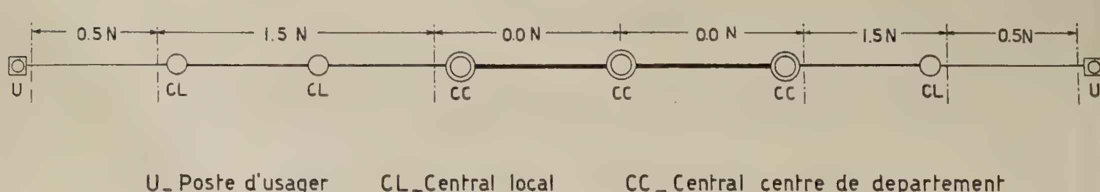


PLATE XI.

Diagram of a telephone connection between two sets in different regions, and assignment of the transmission equivalents.



U = telephone set. CL = local exchange. CC = regional exchange.

[385 (09 .2]

OBITUARY.

Jean-Véronique-Emile VANDERBORGHT,

Former Manager of the Operating Department of the Belgian National Railways.
Former Member of the Permanent Commission of the International Railway Congress Association.

We were very sorry to learn the death on the 29th December last of Mr. Jean-Véronique-Emile VANDERBORGHT, former Manager of the Operating Department of the Belgian National Railways and former member of the Permanent Commission of our Association.

Mr. VANDERBORGHT was born at Louvain on the 21st November 1886. After completing his higher intermediate studies, he entered the service of the Belgian State Railways in 1905. He was assistant station master at Louvain station until the 24th November 1913. He then went to China, where he was employed as Chief Traffic Inspector by the General Railways and Tramways Company of China, for about 13 years. In 1927, he rejoigned the Belgian National Railways and on the 31st August 1932 was promoted to be senior Station Master at the important station of Schaerbeek.

After holding various positions, on the 1st November 1945, he was promoted to the grade of Chief Inspector and became Deputy Traffic Manager. Finally, on the 1st November 1948, he was appointed Traffic Manager, a post which he held up to his retirement at the end of 1951.

Mr. VANDERBORGHT always carried out the duties, with which he was entrusted, most intelligently with a keen sense of reality. His merits earned him numerous distinctions, both Belgian and foreign. In particular, he was a Commander of the Order of Leopold and Commander of the Order of the Crown.

Mr. VANDERBORGHT was made a member

of the Permanent Commission of our Association in 1948. He always showed the greatest interest in the work of the Association, and he took part in the Enlarged Meeting of the Permanent Commission at Lisbon in 1949, as well as in the Rome Congress in 1950. His affable character and competence gained him the esteem of all his colleagues.

We offer his family our sincerest sympathy.

The Executive Committee.

MONTHLY BIBLIOGRAPHY OF RAILWAYS (1)

PUBLISHED UNDER THE SUPERVISION OF

P. GHILAIN,

General Secretary of the Permanent Commission of the International Railway Congress Association.

(MAY 1960)

[016 .385 (02]

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In French.

1960 — **621 .3**
FOURCAULT (L.D.).
Aide-Mémoire Dunod-Electricité. 70e édition.
Paris, Dunod, éditeur. Un volume (10 × 15 cm) de XXVI-358-LXIV pages, avec 104 figures. (Prix : relié 6.80 N.F.)

1959 — **531**
GIET (A.) et GÉMINARD (L.).
Mécanique appliquée. Tomes I et II.
Paris, Dunod, éditeur. Deux volumes de 430 + 268 pages (16 × 24 cm), illustrés de nombreuses figures. (Prix : 1 800 et 1 200 fr. fr.)

1959 — **62 (01**
JEANTET (M.M.).
Le contrôle des matériaux.
Paris, Presses Universitaires de France, éditeur. (Collection : Que sais-je ?). Un volume (11.5 × 17.5 cm) de 128 pages avec 33 figures. (Prix : 200 fr. fr.)

1959 — **621 .333**
RICHTER (R.).
Moteurs monophasés à collecteur. (Traduction de l'allemand.)
Paris, Dunod, éditeur. Un ouvrage (16 × 25 cm) de 392 pages, avec de nombreuses figures. (Prix : relié toile sous jaquette, 69 N.F.)

In German.

1960 — **625 .1 (02**
Elsners Taschenbuch für den bautechnischen Eisenbahndienst. 32. Jahrgang.
Frankfurt (Main), Dr. Arthur Tetzlaff-Verlag. 392 Seiten mit 170 Abbildungen im Text. (Preis : DM 6.—.)

In English.

1960 — **385 (09**
ALLEN (P.) and WHEELER (R.).
Steam on the Sierra. — The narrow gauge in Spain and Portugal.
One volume (10 × 7 1/2 in.) of 203 pages.
London : Cleaner-Hune Press, Ltd., 31, Wright's Lane, W. 8. (Price : 35 s.)

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American Railway Signaling — Principles and Practices. Chapter XXV : **Coded track circuits.**
One brochure of 21 pages, illustrated.
Published by the Signal Section, A.A.R., 59, East Van Buren Street, Chicago 5, Ill.

1960 — **62**
L. LANDON GOODMAN.
Automation Today and Tomorrow.
Publishers : Iota Services Limited, 38, Farringdon Street, London, E.C. 4. (Price : 40 s.)

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Overseas Railways, 1959.
One brochure (11 1/2 × 8 1/2 in.) of 120 pages, fully illustrated.
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Engineering Administration.
One volume of 78 pages.
Sydney : Angus & Robertson. (Price : 21 s. 0 d.)

(1) The numbers placed over the title of each book are those of the decimal classification proposed by the Railway Congress conjointly with the Office Bibliographique International, of Brussels, (See « Bibliographical Decimal Classification as applied to Railway Science ». by L. WEISSENBRUCH, in the number for November 1897, of the *Bulletin of the International Railway Congress*, p. 1509).

[016 .385 (05]

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PUECH (M.). — **Vieillissement des aciers de construction.** Contribution à l'étude de ce phénomène. (1 500 mots & fig.)

1960 624 .9
Acier - Stahl - Steel, février, p. 81.
DECARPENTRIE (E.). — Le **calcul des ossatures étagées et à travées multiples** sous l'action des forces horizontales. (2 000 mots & fig.)

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Annales de l'Institut techn. du Bâtiment et des Trav. Publics, février, p. 149.
BOUVIER (J.). — Etude et perfectionnement d'une **technique du béton immergé.** (1 200 mots, tableaux & fig.)

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MAHIEU (L.). — Méthode intuitive et directe de **calcul organique du béton armé.** (5 000 mots, tableaux & fig.)

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Bull. de l'Ass. Suisse des Electriciens, 12 mars, p. 197.
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Bull. de l'Ass. Suisse des Electriciens, 12 mars, p. 219.
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Bulletin technique de la Suisse Romande. (Lausanne.)

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Les Chemins de fer en 1959. Iran. (500 mots & tableaux.)

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Les **locomotives de manœuvre diesel-électriques** Em 3/3 nos 18801 et suivants. (1 000 mots & fig.)

Génie Civil. (Paris.)

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MACHEFERT-TASSIN (Y.). — La **locomotive bifréquence BB 20103 à bogies monomoteurs et redresseurs au silicium** de la Société Nationale des Chemins de fer Français. (5 000 mots & fig.)

Rail et Traction. (Bruxelles.)

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BAEYENS (F.). — Souvenirs de **dix ans de traction électrique** à la S.N.C.B. (2 000 mots & fig.)

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TOURNEUR. — **L'emploi de la traction Diesel dans les services de manœuvre et de transfert.** (2 000 mots & fig.)

[**016** .385 (05]

II. — PERIODICALS.

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Chittaranjan : Poem in cement and stone. (1 300 words & figs.)

1960 **385** .58
Indian Railways, February, p. 986.
KUNHAPPA (M.). — **Incentive wages to railway workers.** (1 800 words.)

Modern Railroads. (Chicago.)

1960 **625** .172 (73)
Modern Railroads, February, p. 40.
Asphalt promises M/W economy. (2 000 words & figs.)

1960 **625** .232 (73)
Modern Railroads, February, p. 71.
C & NW orders 116 « push-pull » cars. (900 words & figs.)

1960 **621** .431 .72 (73)
Modern Railroads, February, p. 81.
New locomotive keeps fast freight moving. (800 words & figs.)

1960 **625** .13 (73)
Modern Railroads, February, p. 87.
Steel liner protects C & O tunnel. (600 words & figs.)

Modern Transport. (London.)

1959 **621** .431 .72 (42)
Modern Transport, November 21, p. 7.
Main-line all-Diesel depot. (1 800 words & figs.)

1959 **656** .2 (42)
Modern Transport, November 28, p. 5.
FIENNES (G.F.). — **Future for the railway passenger.** (900 words.)

1959 **621** .335 (42)
Modern Transport, December 5, p. 3.
The new electric era. First production of A.C. locomotive for B.R. (1 300 words & figs.)

1959 **656** .2 (42)
Modern Transport, December 12, p. 5.
ARKLE (E.W.). — **Modernisation at work.** (900 words.)

1959 **625** .4 (469)
Modern Transport, December 19, p. 3.
Europe newest Metro to be opened in Lisbon. (1 500 words & figs.)

1960 **656** .2 (42)
Modern Transport, January 23, p. 6.
DUNNETT (L.). — **Government and roads and road transport.** (1 200 words.)

1960 **625** .2 (42)
Modern Transport, January 23, p. 11.
Piccadilly Line. — First of 76 new trains built by Metropolitan-Cammell. (1 600 words & figs.)

1960 **656** .225
Modern Transport, January 23, p. 12.
The problem of the peak. — Rail and road aspects. (*Continued.*) (900 words.)

Railway Age. (New York.)

1959 **656** .225 (73)
Railway Age, November 30, p. 13.
Good TOFC service wins traffic. (1 200 words.)

1959 **656** .225 (73)
Railway Age, November 30, p. 40.
HUDSON (G.C.). — **Piggyback keeps on growing.** (4 000 words & figs.)

1959 **656** .225 (73)
Railway Age, November 30, p. 55.
Piggyback pays its own way. (900 words.)

1959 **625** .236 (73)
Railway Age, December 7, p. 26.
GN mechanizes car cleaning work. (500 words & figs.)

1959 **625** .245 (73)
Railway Age, December 21, p. 59.
A.T.S.F. builds articulated flats. (200 words & figs.)

1960 **656** .2 (73)
Railway Age, January 11, p. 9.
NH : « The countdown has begun ». (1 000 words.)

1960 **656** .2 (73)
Railway Age, January 11, p. 10.
I.C.C. would scan all financing methods. (1 000 words.)

Railway Engineering. (Cape Town.)

1959 **621** .431 .72 (68)
Railway Engineering, December, p. 21.
POULTNEY (E.C.). — **Diesel locomotives for Cape and metre gauge railways.** (2 800 words & figs.)

1959 **621** .335 (42)
Railway Engineering, December, p. 33.
DAY (J.R.). — **Compact 2 500 HP locomotives built for D.C. system of British Railways.** (900 words & figs.)

1960 **621** .133 .7 (68)
Railway Engineering, January, p. 15.
McLLLERON (R.C.). — **Problems of locomotive boiler water supplies in Southern Africa.** (2 000 words & figs.)

1960 **621** .392 (68)
Railway Engineering, January, p. 20 *a*.
AHLERT (W.E.H.). — **The thermit rail welding process — its development and applications** (*to be continued*). (2 000 words & figs.)

The Railway Gazette. (London.)

1960 **621** .431 .72 (489)
The Railway Gazette, January 15, p. 70.
Danish State Railways modernisation. (2 500 words & figs.)

1960 **656** .25 (494)
The Railway Gazette, January 15, p. 74.
Transportable signalbox on Swiss Federal Railways. (1 600 words & figs.)

1960 **625** .13 (42)
The Railway Gazette, January 22, p. 102.
Bridge reconstruction at Evesham, Western Region. (1 000 words & figs.)

1960 **656** .212 (42)
The Railway Gazette, January 22, p. 106.
Remodelling of railway facilities at Peterborough. (1 200 words & figs.)

1960 **625** .244 (941)
The Railway Gazette, January 29, p. 131.
Cold storage and refrigerator transport in Western Australia. (600 words & figs.)

1960 **656** .25 (42)
The Railway Gazette, January 29, p. 132.
Re-signalling of L.T.E. Bow to Upminster line. (1 900 words & figs.)

1960 **385** (061 .5
The Railway Gazette, February 5, p. 158.
Evolution of the International Union of Railways. (2 000 words.)

1960 **624** .63 (73)
The Railway Gazette, February 5, p. 160.
North American road overbridge design. (900 words & figs.)

1960 **656** .2 (42)
The Railway Gazette, February 5, p. 162.
AYERS (C.). — **Developing the rail travel habit in the North Eastern Region.** (2 400 words & figs.)

Diesel Railway Traction. (London.)

1960 **625** .174
Diesel Railway Traction, January, p. 16.
Diesel snow-plough. (300 words & figs.)

1960 **621** .431 .72 (44)
Diesel Railway Traction, January, p. 17.
French panoramic railcars. (3 600 words & figs.)

1960 **621** .431 .72
Diesel Railway Traction, January, p. 22.
General trends in Diesel traction. (5 400 words & figs.)

1960 **621** .431 .72 (4)
Diesel Railway Traction, February, p. 58.
Diesel motive power behind the iron curtain. (2 000 words & figs.)

Railway Locomotives and Cars. (New York.)

1960 **625** .236 (73)
Railway Locomotives and Cars, January, p. 17.
Great Northern cuts car cleaning costs. (1 000 words & figs.)

1960 **621** .335 (73)
Railway Locomotives and Cars, January, p. 24.
What to do about traction gear wear. (2 000 words & figs.)

1960 **625** .245 (73)
Railway Locomotives and Cars, January, p. 35.
AT and SF articulates piggyback cars. (1 400 words & figs.)

1960 **621** .431 .72 (73)
Railway Locomotives and Cars, February, p. 17.
Alco DL-640 : power for fast freights. (600 words & figs.)

1960 **656** .225 (73)
Railway Locomotives and Cars, February, p. 24.
B and O 'articulates' piggyback cars. (400 words & figs.)

1960 **656** .225 (71)
Railway Locomotives and Cars, February, p. 40.
Axle generators on C.P.R. piggybacks. (500 words & figs.)

Railway Magazine. (London.)

1960 **621** .335 (42)
Railway Magazine, February, p. 122.
High-voltage electric locomotive for British Railways. (1 600 words & figs.)

Railway Signaling and Communications. (New York.)

1960 656 .25 (73)
Railway Signaling and Communications, February, p. 15.
C.T.C. signals clear automatically. (2 000 words & figs.)

Railway Track and Structures. (Chicago.)

1960 625 .13 (73)
Railway Track and Structures, February, p. 34.
Arch failure blocks 1 500-ft. tunnel P. & W.V. (1 600 words & figs.)

Trains Illustrated. (London.)

1960 621 .335 (42)
Trains Illustrated, January, p. 37.
The first B.R. type « A » 25 kV A.C. electric locomotive. (600 words & fig.)

1960 621 .338
Trains Illustrated, January, p. 40.
The Stone-Mekydro transmission. (1 900 words & figs.)

1960 656 .22 (45)
Trains Illustrated, March, p. 140.
FREEMAN ALLEN (G.). — **Europe's most luxurious express.** (4 000 words & figs.)

In Hungarish (= 494.511).

Közlekedéstudományi Szemle. (Budapest.)

1959 625 .14 = 494.511
Közlekedéstudományi Szemle, mars, p. 123.
TÖRÖK (K.). — **Mesures des contraintes des rails par des procédés acoustiques.** (2 000 mots & fig.)

1959 656. 224 = 494.511
Közlekedéstudományi Szemle, avril, p. 137.
TURANYI (I.). — Les **problèmes importants de principe et de méthodologie dans le partage du trafic voyageurs.** (8 300 mots & fig.)

In Italian.

Giornale del Genio Civile. (Roma.)

1959 624 .2
Giornale del Genio Civile, dicembre, p. 1043.
VITTORIA (V.). — **Il solaio a fungo e la trave con momento d'inerzia infinito agli estremi.** (8 000 parole, tabelle & fig.)

Ingegneria Ferroviaria. (Roma.)

1959 624 .2
Ingegneria Ferroviaria, dicembre, p. 1077.
POLSONI (G.). — **Ridimensionamento delle travi continue.** (3 000 parole & fig.)

1959 725 .31 (45)
Ingegneria Ferroviaria, dicembre, p. 1083.
VIALE (U.) & SAMUELLI-FERRETTI (A.). — **Le strutture di copertura della nuova stazione** di Napoli Centrale. (3 000 parole, tavole & fig.)

1959 625 .212 (45)
Ingegneria Ferroviaria, dicembre, p. 1093.
MALVEZZI (L.). — La **fabricazione delle sale montate** allo Stabilimento « Ilva » di Lovere. (3 500 parole & fig.)

1959 625 .234
Ingegneria Ferroviaria, dicembre, p. 1103.
NOVIGNO (S.). — **Riscaldamento elettrico** dei treni viaggiatori. (3 500 parole & fig.)

1959 656 .2 (73)
Ingegneria Ferroviaria, dicembre, p. 1120.
BONACINA (E.). — Tendenze recenti e situazione economica delle **ferrovie americane.** (5 000 parole & tabelle.)

Politica dei Trasporti. (Roma.)

1960 656 .234 (45)
Politica dei Trasporti, gennaio, p. 24.
SAVOJA (A.). — **Il costo dei trasporti degli abbonati operai, impiegati e studenti** sulle F.S. (2 500 parole.)

Trasporti Pubblici. (Roma.)

1959 656 .257 (45)
Trasporti Pubblici, novembre, p. 1633.
DARD (M.). — **I nuovi impianti elettrici** della stazione di Trieste Centrale. (2 600 parole & fig.)

1959 625 .5
Trasporti Pubblici, novembre, p. 1647.
La **méthode magnéto-inductive d'examen des câbles.** (4 000 parole.)

1959 656 .225
Trasporti Pubblici, dicembre, p. 1759.
FONTANELLA (G.). — I **servizi containerizzati** nel trasporto di merci. (1 500 parole.)

1959 621 .33 (45)
Trasporti Pubblici, dicembre, p. 1783.
DARD (M.). — Da **Torino a Bari con treni elettrici.** (1 500 parole & fig.)

1959 621 .33 (45)
Trasporti Pubblici, dicembre, p. 1789.
Elettrificata la Pescara-Sulmona. (1 200 parole & fig.)

In Netherlands.

De Ingenieur. (Den Haag.)

1960 **625** .42 (492)
De Ingenieur, nr 10, 4 maart, p. A. 115 en nr 11, 11 maart, p. A. 131.
PLANTEMA (G.). — Het **Metroplan Rotterdam.** De Metro, een integrerend deel van het vraagstuk der oeververbindingen in Rotterdam. (6 000 woorden & fig.)

1960 **625** .213
De Ingenieur, nr 10, 4 maart, p. W. 61.
PACEJKA (H.B.). — Theoretische beschouwingen over **het gedrag van luchtveren.** (6 000 woorden & fig.)

Spoor- en Tramwegen. (Den Haag.)

1959 **385** .113 (45)
Spoor- en Tramwegen, nr 27, 31 december, p. 436.
HUPKES (G.). — Het **jaarverslag 1957-1958 van de Italiaanse Staatsspoorwegen.** (2 500 woorden & fig.)

1959 **656** .225
Spoor- en Tramwegen, nr 27, 31 december, p. 443.
VAN LIESHOUT (J.). — Wéér een voorbeeld van **efficiënt spoorwegvervoer.** (1 000 woorden & fig.)

1960 **656** .261 (492)
Spoor- en Tramwegen, nr 1, 14 januari, p. 1.
DIJKXHOORN (Th. D.). — **Nieuwe lijndienstloods** van Van Gend & Loos. (2 000 woorden & fig.)

1960 **625** .28
Spoor- en Tramwegen, nr 1, 14 januari, p. 7.
ENTER (H.F.). — **Moderne trekkracht** voor een modern bedrijf. (1 000 woorden & fig.)

1960 **385** .113 (492)
Spoor- en Tramwegen, nr 2, 28 januari, p. 17.
De **N.V. Nederlandsche Spoorwegen** in 1959. (3 000 woorden & fig.)

1960 **656** .225 (44)
Spoor- en Tramwegen, nr 2, 28 januari, p. 24.
Het **vervoer van zware wegvoertuigen** op platte wagens bij de S.N.C.F. De « Poids-lourd Express ». (800 woorden & fig.)

1960 **625** .245 (492)
Spoor- en Tramwegen, nr 2, 28 januari, p. 25.
KARSKENS (J.J.). — **Silowagens** NS nrs 99000-99099. (1 500 woorden & fig.)

In Polish (= 491.85).

Przeglad Kolejowy. (Varsovie.)

1959 **656** .225 = 491 .85
Przeglad Kolejowy, mars, p. 98.
KACZMARKIEWICZ (B.). — Méthode de **calcul des dépenses de transport des marchandises** pour les différents types de wagons. (3 400 mots.)

In Portuguese.

Boletim da C.P. (Lisboa.)

1960 **625** .42 (469)
Boletim da C.P., fevereiro, p. 7.
O **Metropolitano de Lisboa.** (1 000 palavras & fig.)

Gazeta dos Caminhos de ferro. (Lisboa.)

1960 **385** (09 .3 (469)
Gazeta dos Caminhos de ferro, nº 1731, 1 de Fevereiro, p. 575; nº 1732, 16 de Fevereiro, p. 587; nº 1733, 1 de Março, p. 603.
DE QUADROS ABRAGAO (F.). — No **Centenário dos Caminhos de Ferro** em Portugal. Algumas notas sobre a sua história. (*Continua.*) (5 500 palavras.)

In Russian (= 491.7).

Electritcheskaïa i Tyeplovosnaïa Tyaga. (Moscou.)

1959 **656** .2 = 491 .7
Electritcheskaïa i Tyeplovosnaïa Tyaga, janvier, p. 3.
MILOUKINE (F.P.) — Nouvelle étape dans l'**évolution du transport ferroviaire.** (3 600 mots & fig.)

1959 **621** .331 = 491 .7
Electritcheskaïa i Tyeplovosnaïa Tyaga, janvier, p. 11.
SCOBELEV (K.I.). — **Supériorité incontestable du courant alternatif.** (900 mots.)

1959 **621** .431 .72 = 491 .7
Electritcheskaïa i Tyeplovosnaïa Tyaga, janvier, p. 13.
FOUFRYANSKY (N.A.). — Quelques problèmes relatifs au **perfectionnement de la traction Diesel.** (700 mots.)

1959 **625** .26 = 491 .7
Electritcheskaïa i Tyeplovosnaïa Tyaga, janvier, p. 15.
TEMEROV (B.K.). — Accélération des préparatifs d'un **atelier de réparation de nouveaux types de locomotives.** (2 800 mots.)

1959 **625** .234 = 491 .7
Electritcheskaïa i Tyeplovosnaïa Tyaga, janvier, p. 23.
OSOLINE (A.K.) et KRYLOV (V.I.). — **Distributeur d'air n° 292 pour les trains de voyageurs.** (1 500 mots & fig.)

1959 **621** .333 = 491 .7
Electritcheskaïa i Tyeplovosnaïa Tyaga, janvier, p. 32.
KOULAGINE (I.K.) et RYABNY (V.P.). — **Expérience d'exploitation de redresseurs à compensation** et génération de la puissance réactive. (800 mots & fig.)

1959 **621** .335 = 491 .7
Electritcheskaïa i Tyeplovosnaïa Tyaga, février, p. 9.
DEMTCHENKO (D.A.). — La **conduite des locomotives électriques par équipes de rechange** sur longues sections de ligne desservies par un dépôt de machines. (3 100 mots & fig.)

1959 **621** .94 = 491 .7
Electritcheskaïa i Tyeplovosnaïa Tyaga, février, p. 17.
PAVLENKO (I.K.). — **Modernisation des tours à roues.** (1 200 mots & fig.)

1959 **621** .332 = 491 .7
Electritcheskaïa i Tyeplovosnaïa Tyaga, février, p. 22.
WEINSTEIN (B.Z.). — Moyens pour abaisser les frais des **dispositifs d'alimentation en énergie.** (1 000 mots.)

1959 **656** .2 = 491 .7
Electritcheskaïa i Tyeplovosnaïa Tyaga, mars, p. 1.
TARASSOV (G.F.). — Nouvelles règles pour l'**exploitation technique des chemins de fer.** (3 200 mots.)

1959 **621** .431 .72 = 491 .7
Electritcheskaïa i Tyeplovosnaïa Tyaga, mars, p. 10.
SOROKHOVITCH (A.E.) et GLOUCHITZKY (I.V.). — **Station automatique de chargement des batteries d'accumulateurs** de locomotives Diesel. (2 250 mots & fig.)

1959 **621** .332 = 491 .7
Electritcheskaïa i Tyeplovosnaïa Tyaga, mars, p. 17.
VOLOGUEJANINE (Y.N.). — Nouveau schéma de **protection des lignes électriques de transmission** contre les courts-circuits à la terre. (800 mots & fig.)

1959 **621** .332 = 491 .7
Electritcheskaïa i Tyeplovosnaïa Tyaga, mars, p. 23.
GERASINE (I.F.). — Une **ceinture de sauvetage sûre pour les monteurs des lignes de contact.** (750 mots & fig.)

Jelesnodorojnuy Transporte. (Moscou.)

1959 **625** .17 = 491 .7
Jelesnodorojnuy Transporte, mars, p. 39.
ZOLOTARSKIY (A. Ph.) et PLATOV (V.I.). — Les perspectives d'une **mécanisation complète des grandes réparations de la voie.** (1 400 mots & fig.)

1959 **656** .224 = 491 .7
Jelesnodorojnuy Transporte, mars, p. 43.
POUSINE (A.I.) et PHYEDOROV (V.A.). — Les **moyens de perfectionnement du trafic voyageurs.** (2 500 mots.)

1959 **625** .17 = 491 .7
Jelesnodorojnuy Transporte, mars, p. 60.
JEREBINE (M.I.). — Comment améliorer le système du contrôle et de l'appréciation de **l'état de la voie.** (900 mots.)

1959 **621** .438 = 491 .7
Jelesnodorojnuy Transporte, avril, p. 16.
BARTOCH (E.T.) et CHEVTCHENKO (L.A.). — Les perspectives de l'utilisation des **locomotives à turbines à gaz.** (2 500 mots & fig.)

1959 **656** .222 .4 = 491 .7
Jelesnodorojnuy Transporte, avril, p. 20.
CHOULJENKO (P.A.). — Le **graphique des trains** et l'organisation de l'utilisation efficace de nouveaux systèmes de traction. (2 200 mots & fig.)

1959 **621** .331 = 491. 7
Jelesnodorojnuy Transporte, avril, p. 27.
KIYENYA (I.M.). — Moyen important pour augmenter le **rendement des sous-stations de traction.** (1 500 mots & fig.)

1959 **625** .17 = 491 .7
Jelesnodorojnuy Transporte, avril, p. 30.
YOUPHYERYEV (V.M.). — Le perfectionnement du système d'alimentation en énergie électrique des **travaux de voie.** (2 200 mots & fig.)

1959 **656** .212 = 491 .7
Jelesnodorojnuy Transporte, avril, p. 36.
VYETOUKHOV (E.A.). — **Location rationnelle des gares de marchandises** dans les grandes villes. (2 200 mots.)

1959 **656** .212 .5 = 491 .7
Jelesnodorojnuy Transporte, avril, p. 44.
PYETROVA (S.V.). — La **spécialisation des voies de triage d'après les charges.** (2 800 mots.)

1959 **625** .212 = 491 .7
Jelesnodorojnuy Transporte, avril, p. 53.
SOKOLOV (I.G.). — Les **essieux creux pour le matériel roulant ferroviaire** et la technologie de leur production (1 400 mots & fig.)

Transportnoïe Stroïtelstvo. (Moscou.)

1959 **625** .1 (47) = 491 .7
Transportnoïé Stroïtelstvo, janvier, p. 13.
WERTZMANE (G.S.) et BYÉLENSKIY (N.P.). — Projet des normes nouvelles et des conditions techniques pour les **études de nouvelles lignes de chemins de fer.** (2 800 mots.)

1959 **691** = 491 .7
Transportnoïé Stroïtelstvo, janvier, p. 29.
KOUTSENKO (V.N.) et KOTYER (V.A.). — Procédé de fabrication des **constructions de travées en béton précontraint** à l'aide de la méthode d'un armement ininterrompu. (1 400 mots & fig.)

1959 **621** .332 = 491 .7
Transportnoïé Stroïtelstvo, janvier, p. 39.
KRONFELD (B.D.). — Expérience d'installation de **pylônes en béton armé des lignes de contact** par un procédé d'affouillement. (700 mots & fig.)

1959 **625** .12 = 497 .1
Transportnoïé Stroïtelstvo, janvier, p. 46.
TITOV (V.P.). — **Déformations des talus de fossés,** causées par congélation et dégel du terrain. (2 000 mots & fig.)

1959 **624** (51) = 497 .1
Transportnoïé Stroïtelstvo, janvier, p. 52.
PEN MIGNE. — Evolution dans la **construction des ponts** en République populaire de Chine. (1 500 mots & fig.)

1959 **621** .332 = 491 .7
Transportnoïé Stroïtelstvo, février, p. 13.
SIDOROV (V.I.) et KOUZMINOV (V.A.). — Le creusement par vibration des fosses de fondation de **pylônes en béton armé des lignes de contact.** (1 300 mots & fig.)

1959 **621** .392 = 497 .1
Transportnoïé Stroïtelstvo, février, p. 40.
TKATCHENKO (F.S.). — **Recharge des pièces par soudure électrique automatique** à plusieurs électrodes. (1 300 mots & fig.)

In Russian (+ German and Chinese) (= 491.7).

Bulletin de l'Organisation de Collaboration des Chemins de fer (OSShD). (Varsovie.)

1959 **621** .431 .72 = 491 .7
Bulletin de l'OSShD, n° 3, p. 10.
KALININE (S.S.). — Les **trains Diesel pour les transports de voyageurs.** (2 500 mots.)

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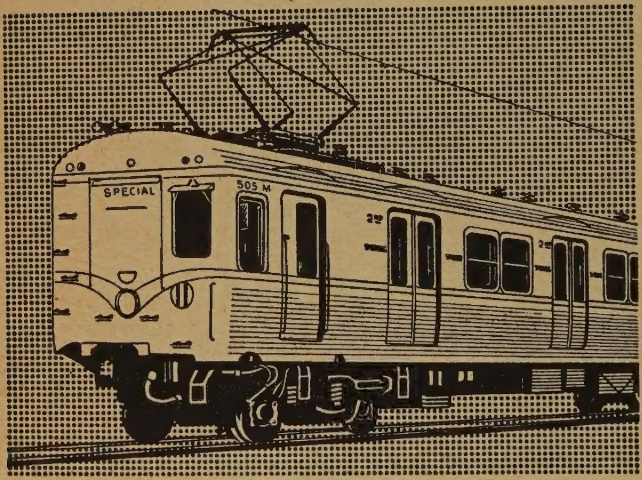
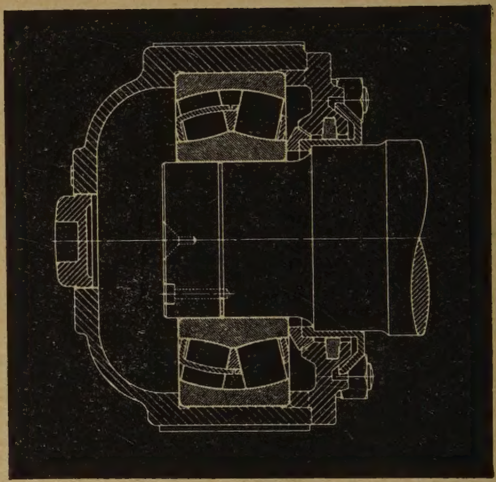
Australian suburban trains with SKF roller bearing axleboxes

Electric multiple-unit trains of the type shown here — in all, 90 motor coaches and 120 trailer coaches — have been put into service on Melbourne's suburban lines by Victorian Government Railways. During peak hours there are seven coaches in each train — three motor and four trailer. In off-peak hours, however, four-coach train sets are used, comprising two motor coaches and two trailer coaches. The maximum speed is approximately 75 m.p.h. and all axles are fitted with SKF roller bearing axleboxes.





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